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SEASONAL DISTRIBUTION AND MOVEMENT OF RADIO TAGGED WALLEYE AND LAKE STURGEON IN THE VICINITY OF THE PROPOSED MATTAGAMI RIVER HYDROELECTRIC EXTENSIONS

Report No 91-104-K

R.S. McKinley, R.W. Sheehan and H. Kowalyk
Biological Research Section
Chemical Research Department

ABSTRACT

The objective of this study was to determine the seasonal distribution and movement of radio tagged lake sturgeon and walleye in the vicinity of the proposed Mattagami River Hydroelectric Extensions. Results indicated that the majority of the radio tagged lake sturgeon were 30 km south of Little Long Generating Station and therefore were not vulnerable to either passage through the station or down the diversion channel at Adam Creek. Radio tagged walleye and sturgeon were present in the downstream end of Adam Creek during the spring freshet spawning period.

job	file	date	report no
34-144 and 34-542	837.317	April 17, 1991	91-104-K

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EXECUTIVE SUMMARY

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R.S. McKinley, R.W. Sheehan and H.E. Kowalyk

The objectives of this study were to: 1) determine the presence/absence of lake sturgeon in the forebay of Little Long GS prior to, during and following spring freshet (1989/1990), using radio telemetry, and assess whether any of those fish were swept into the Adam Creek diversion channel during freshet, 2) determine if any of the radio tagged walleye and/or sturgeon moved into the downstream end of Adam Creek from the Mattagami River during spring freshet and the onset of spawning, 3) determine seasonal distribution patterns (distance travelled, diurnal activity patterns) for lake sturgeon and 4) assess the limitations of radio-telemetry for such applications and make recommendations for improvement. Fifty, uniquely radio tagged, adult sturgeon and fifteen walleye were tracked once a month prior to and following spring freshet using a fixed-wing aircraft. During freshet, these fish were tracked weekly. In addition, fixed antennae stations were set-up to monitor any passage through hydroelectric facilities as well as their spillage downstream into the Adam Creek diversion channel via the control structure. The stations also served to document movement up into the downstream end of the creek during spring freshet and the onset of spawning. Results indicated that the majority of the radio tagged lake sturgeon in the headpond during 1989 and 1990 were at least 30 km south of the hydraulic facilities during spring freshet, and therefore did not appear to be vulnerable to either passage through any of the stations or being swept into Adam Creek via its control structure. Of the radio tagged sturgeon that were present in the forebay, only one individual was recorded as passing through the Little Long GS spillway. At least 50% of the lake sturgeon radio tagged north of Kipling GS station chose to inhabit a 30 m deep pool, located immediately below the stations' spill structures, during the freshet periods of 1989 and 1990. Lake sturgeon and walleye were present in the downstream end of Adam Creek during the spring freshet spawning period.

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34-144 and 34-542	837.317	April 17, 1991	91-104-K

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To: Dr. W.R. Effer
Manager
Environmental Studies & Assessments Dept
Design & Development Div - Generation

SEASONAL DISTRIBUTION AND MOVEMENT OF RADIO TAGGED WALLEYE AND LAKE STURGEON IN THE VICINITY OF THE PROPOSED MATTAGAMI RIVER HYDROELECTRIC EXTENSIONS

1. INTRODUCTION

This study evolved from the results of the Environmental Workshop (ESSA 1986) which identified baseline biological objectives for investigating potential environmental effects of the proposed Mattagami River Hydroelectric Extensions, along with subsequent additional technical discussions with the Ministry of Natural Resources. Much of the baseline data have been collected and is outlined in OHRD Report 89-34-K. Results of both these studies were utilized in the preparation of the Mattagami River Hydroelectric Extensions Environmental Assessment document.

A considerable effort has been spent on documenting the potential effects of hydroelectric development on resident fish stocks (Waterpower 1987 and EPRI Conference on Fish Protection 1987). The majority of this effort has been afforded to documenting turbine related mortalities and the development of subsequent mitigative solutions. Little effort, however, has been spent on the influence of hydropower development on the movement, reproductive behavior and seasonal distribution patterns of resident fish species. Identification of these activities would enhance the management of resident fish stocks near future and existing hydraulic stations.

The lack of reliable information on fish movement and density can be largely attributed to limitations in the sampling design and procedure employed. Such information was usually based on direct observation or interpreted from capture-recapture data of a number of tagged individuals. The time interval between sampling or recaptures has been known to vary from days to years (Crossman 1977). Continuous monitoring of the marked fish is required to adequately predict any potential change in fish stocks or habitat utilization as a result of the construction or operation of a generating facility.

Typically, conventional netting practices constituted a large part of most sampling procedures. Unfortunately, the use of nets may be consumptive, not only to the targeted species but to other non-targeted species. In addition, data collected from the deployment of nets can neither accurately account for the continual movement of fish nor reflect a habitat preference. Seldom is *a priori* knowledge of their distribution available to assist in the deployment of nets. Nets can also be hazardous for a crew to deploy in close proximity to an operating station, and therefore may not be placed in the required location for the correct evaluation of a potential mitigative technique.

The use of conventional practices is not, however, to be entirely dismissed, since estimates of age, size, condition, sex and the identification and value (calorific) of their prey items often requires the capture and sacrificing of a few individuals. It may, however, be possible that through the application of telemetry, information on migratory behavior can also be assessed.

Recent developments made in the use of radiotelemetry (*i.e.* - tag life/reliability/signal strength) for use in terrestrial ecology, bio-medical research and automatic and remote data acquisition studies, may in the future yield the desired information in aquatic applications. Development of this technology for use in determining fish movement in close vicinity of an active station would certainly provide: 1) reliable and continuous data acquisition in real time, 2) decreased labor cost by reducing the size of the site crew, 3) decreased potential risks to the site crew and 4) a non-consumptive method of obtaining fisheries data (seasonal distribution patterns, reproductive strategy, diurnal activity patterns).

The objectives of this study (1989 and 1990) were to: 1) using radiotelemetry to determine the presence/absence of lake sturgeon in the forebay of Little Long GS prior to, during and following spring freshet (1989), using radiotelemetry, and assess whether any of those fish are swept into the Adam Creek diversion channel during freshet, 2) determine if any of the radio tagged walleye and/or lake sturgeon are present in the downstream end of Adam Creek during spring freshet and the onset of spawning, 3) determine the seasonal distribution patterns for lake sturgeon within the defined study area throughout 1989, and 4) assess the limitations of radiotelemetry for such applications and make recommendations for improvement.

2. METHODS AND MATERIALS

2.1 Study Area

The study area was restricted to an area bordered by the intersection of Highway 11, connecting Smooth Rock Falls and Kapuskasing, and the Groundhog River in the south to Grand Rapids in the north. Situated approximately in the middle of the two outside borders and about 80 km north of Kapuskasing is the proposed Mattagami River Hydroelectric Development Extensions. This

extension consists of four hydroelectric facilities (from south to north - Little Long GS, Smoky Falls GS, Harmon GS and Kipling GS) of varying capacity. (Figure 1) Three of the four stations are operated as peaking stations by Ontario Hydro. They utilize reservoir storage to withhold riverflow and the release schedule is a function of water availability. The exception is Smoky Falls GS which is owned and operated by Spruce Falls Power and Paper Co. This station provides the power to run the company's pulp mill in Kapuskasing. Due to the lower power generating capacity of Smoky Falls GS compared to the other three stations, Ontario Hydro releases water, typically during spring freshet or following heavy rainfalls, down a diversion channel (Adam Creek) via controlled spill structures. Little Long GS can, if required, spill excess water from the spring freshet into Adam Creek via its control structures. Unfortunately, any fish in the immediate vicinity of the initial station (Little Long) or the diversion channel may be either included in the water destined for each of the stations or swept into the diversion channel. Potentially, fish that are swept into Adam Creek will subsequently be confined to pools since water flow in the creek is negligible following freshet. The negligible water flow would also negatively influence any fish which may have entered and spawned in the lower half of Adam Creek during the freshet.

2.2 Mean Flow - Little Long GS, Spill and Adam Creek

Spring freshet in 1989, as represented by the initiation and termination of flow at Adam Creek control structure, began May 2 and continued until June 22 (six weeks) on the Mattagami River (Figure 2). The spill through the Little Long control structures was very intermittent and occurred only on a daily basis. The increased flow through Little Long GS coincided with the start of freshet and remained constant until the end of July. A similar peak in flow at Little Long GS occurred in the fall. The increased flow during the fall was considerably shorter in duration (one month compared to approximately four months in the summer).

Freshet in 1990 occurred earlier (April 25) and lasted longer (July 14) than in 1989. Flow at the Adam Creek Control Structure was considerably more variable in 1990 than in 1989. Overall, more water was discharged through the control structures at Adam Creek in 1990 than in 1989. In 1990, the control structure was initially closed at the end of June but then re-opened at the beginning of July and continued to pass water for the next two weeks. This second spillage event at the Adam Creek was less than 10% of the spillage in May. Unique to 1990, a second spill occurred at Adam Creek during the fall. Consistent with the increased spilling event at Adam Creek, peak generation at the Little Long GS was extended in 1990 by approximately two weeks over the event in 1989. Water flow through the Little Long GS spillway was intermittent and did not exhibit any characteristic pattern.

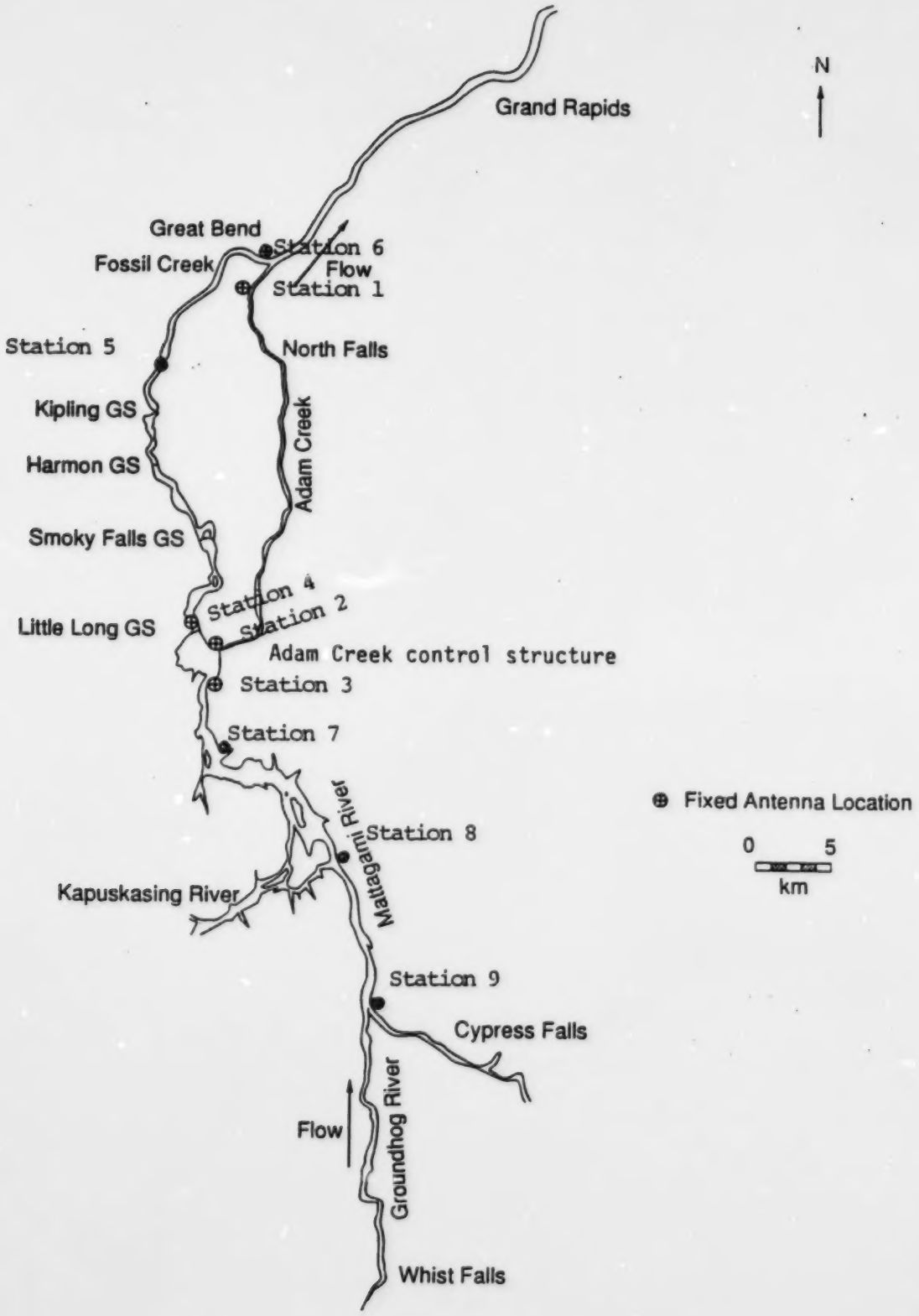

FIGURE 1

MATTAGAMI RIVER RADIO TELEMETRY STUDY AREA, 1989/1990

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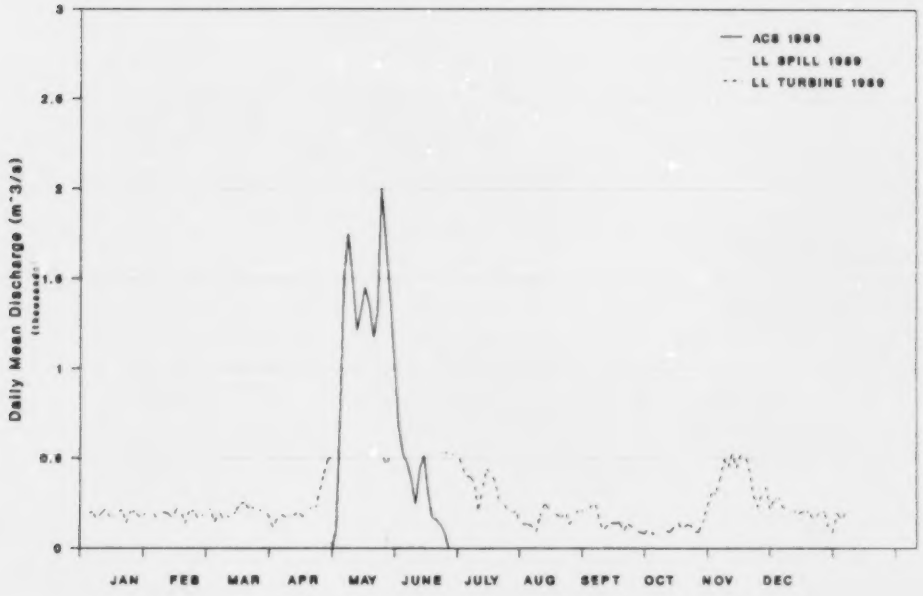


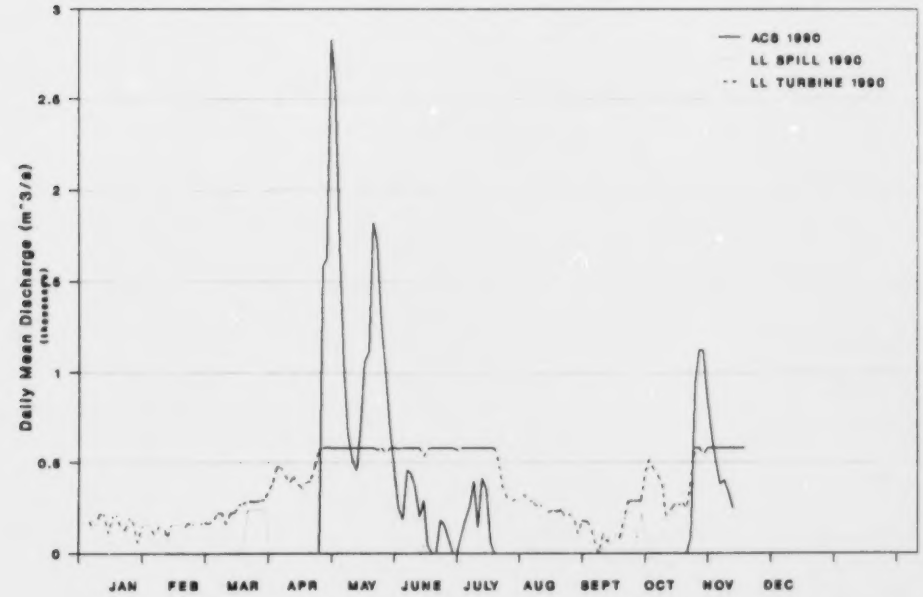


Figure 2

Daily mean discharge (m^3/s) for Little Long Spill, Little Long Turbine and Adam Creek - 1989 and 1990

2.3 Fishing Procedures

Gill nets were systematically employed to collect lake sturgeon and walleye for radio tagging. Lake sturgeon were collected between May 30 and June 14, 1988 using 1-5 panel sturgeon nets (15.2 m x 1.8 m panels - stretched mesh 15 cm). These nets were used to collect sturgeon south of Little Long forebay, immediately north of the control structure on Adam Creek, north of the North Falls on Adam Creek and 3 km downstream of the Kipling GS. Walleye were collected during October, 1988 using experimental gill nets (15.2 m x 1.5 m panels - stretched mesh - 6 - 12.7 cm). Collection of walleye was restricted to the confluence of Adam Creek and the Mattagami River. Generally all net sets for sturgeon and walleye were for 24 h. An exception was the sets in the pools north of the Adam Creek Control Structure where the number of sturgeon required for radio tagging were obtained from sets of only 2 h.

In 1989/90, a limited fishing effort was conducted during and following the spring freshet (during ice free conditions) using experimental gill (15.2 m x 1.5 m - mesh 6 - 15 cm) and sturgeon nets (15.2 m x 1.8 m panels - mesh 15 cm). Sampling was generally conducted in the tailrace of Kipling GS and/or north of the interface of the Mattagami River and Little Long GS forebay. In addition, an attempt was made to have a few of the fishing locations coincide with the location of detected radio signals. This attempt to re-capture previously radio-tagged sturgeon and/or walleye was to allow for an assessment of their condition (*i.e.* spawning condition, influence of the radio tag).

2.3.1 Meristics

All fish caught in 1988 were identified and enumerated. All live sturgeon and walleye captured were weighed (kg), measured (total and/or fork length - cm) and tagged with a Floy internal anchor tag before being released. Any sturgeon and/or walleye found dead in the nets were examined for spawning condition and sexed. In addition to collection of the above meristics, live sturgeon over one meter in length were retained for radio tagging. This size of lake sturgeon has been reported as being within the range at which first spawning may occur (Magnin 1966). These data were reported in OHRD Report C88-108-K. In addition to the adult sturgeon, walleye, over 325 mm, were also retained for radio tagging. This length falls within the range suggested by Scott and Crossman (1973) for the size at which males (279 mm) and females (356 - 432 mm) become sexually mature.

All fish caught in 1989 and 1990 were also identified and enumerated. All live sturgeon were weighed, measured (total/fork length) and tagged with a Floy internal anchor tag before being released. A few of the sturgeon caught were sacrificed for sex determination, spawning condition and mercury and mitochondria DNA analyses.

2.4 Radio Telemetry

Radiotelemetry equipment manufactured by LOTEK ENG Inc. and Cedar Creek (1989 only) was used. Two types of radio transmitters were employed, location tags (50 sturgeon and 15 walleye) and ten location/temperature sensing tags (sturgeon only). The sixty-five, uniquely coded tags are designed to broadcast at frequency intervals of 10 kHz within an operating band of 50.000 to 51.999 MHz. The tags operate within a temperature range of -40 to 50^{0}C and with a one kHz accuracy. The lifespan (battery life) of the juvenile and adult sturgeon transmitters was approximately 12 and 28 months, respectively. The lifespan of the walleye transmitters were 12 months. An attempt was made to follow a recommendation from the study of Ross and McCormick (1981) that the weight of the radio tag be less than 1.5% of the weight of the fish. A 30 cm whip antenna extended from each transmitter. These tags were used to provide information on the whereabouts of each marked sturgeon throughout the study area. The ten temperature sensing tags provided ambient water temperature data about the individual sturgeon. These data were correlated to the migratory and reproductive behaviour of sturgeon and the onset of spring freshet. The walleye tags were used to provide information on the use of Adam Creek by walleye during the spring freshet.

2.4.1 Tagging Procedure

Fifty adult sturgeon (approximately 1.0 m or more in length) and ten juvenile sturgeon (<75 cm, total length) were collected using gill nets. No more than 6 individuals were retained in a portable holding tank at any one time prior to the external attachment of a radio transmitter. The tagging procedure required one person manually positioning each sturgeon (no anesthetic used) on a level surface while a second person used spinal needles to produce 1.0 mm holes through or underneath the fourth and seventh dorsal scutes. Spinal needles were used to thread the transmitter's attachment wire through these holes and back to the transmitter where it was permanently fastened. The threading of the wire through a teflon back plate, situated on the opposing dorsal side of the fish, was used to prevent erosion of flesh by the attachment wire. Both a bactericide (Betadine) and a fungicide (malachite green) were applied to the outside of each wound. The entire procedure generally took less than three minutes to completion.

Following tagging, all marked fish were placed in a flow-through corral created along the shore of the river until they were strong enough to swim away. None of the sturgeon outfitted with a radio transmitter died in the corral as a result of the tagging procedure.

Of the forty adult sturgeon tagged in 1988, 19 were outfitted with radio transmitters in the headpond of Little Long GS, 6 just below the Adam Creek Control Structure, 3 north of the north waterfalls on Adam Creek and 12 north of Kipling GS. The additional ten adult sturgeon outfitted with

location/temperature sensing radio transmitters in October 1989 were released 3 km south of the confluence of Little Long forebay and the Mattagami River. The tracking of these individuals was restricted to 1990.

All fifteen adult walleye to be radio tagged were initially held in a flow-through holding cage, constructed from snow fence material, for approximately 12 hours prior to any surgery. This period of time was designed to reduce the stress of capture from gill nets and to assess the general condition of each walleye following capture (*i.e.* - latent mortality, any wounds, removal of any weakened fish) prior to surgery.

Each of the walleye were anesthetized using Tricane Methane Sulfonate (MS222, 3 g/20 l water). Once a walleye was anesthetized (*i.e.* became unstable, belly-up), it was placed upside down on a V-shaped surgical table which had been designed so that only the head of the fish was submerged in fresh river water. After the removal of a scale sample, a 3 cm incision, approximately 5 cm posterior to the insertion of the pelvic fins and 2 cm left of the mid-ventral line, was made. The 30 cm whip antenna of the cylindrical radio tag (1.7 cm diameter x 7 cm long) was threaded into a 1 mm diameter brass tube, sharpened at one end, which in turn was inserted into the incision and pushed posteriorly along the inside of the body cavity until approximately 10 to 15 cm from the caudal fin where the tube exited the cavity through the body wall. The tubing was removed leaving the whip antenna in place. The remainder of the radio tag was then placed in the body cavity and pushed slightly forward. One mL of Liquamycin-LP (antibiotic) was injected into the body cavity via the incision just prior to suturing. Also prior to suturing, an attempt was made to sex each individual. The incision was closed using three independent sutures, approximately 1 cm apart. The suturing material (permanent) was silk (2-0, by ETHICON Ltd). Malachite green (fungicide) was applied to the outside of each wound (incision and exit point for antenna). The surgical procedure averaged less than four minutes per fish.

The tagged walleye were held in a plastic enclosure (0.5 m^3) containing fresh river water until they regained fin control. Fish were then released at the mouth of Adam Creek. The recovery period averaged less than 3 minutes.

The above procedure followed suggestions made by D. Wood (MNR, Lindsay District), who has had extensive experience in the radio tagging of walleye.

2.4.2. Tracking Procedures

Movement of the marked fish in the study area was remotely monitored using radiotelemetry. The procedure involved the use of fixed antennae stations (4 in 1989 and 5 in 1990), and a properly outfitted boat and a fixed wing aircraft (DH turbo and piston Beaver).

a) Tracking using a Boat

Preliminary tracking of the radio tagged lake sturgeon was conducted using a three element Yagi antenna mounted onto a boat. The antenna was constructed by reducing boom length and element number of a Cushcraft Model A50-5 Yagi antenna. ARRL (American Radio Relay League) specifications dictated element lengths and spacing. Tuning equipment included a General Electric portable radio transmitting at 50.4 MHz and a Kenwood SW100A SWR (standing wave ratio) bridge. The tuning procedure has been outlined in OHRD Report C88-108-K.

The antenna was connected to a receiver which had been previously programmed with the target frequencies. The radio receiver automatically searched for each frequency for four seconds as the boat journeyed along the river at a constant speed. Once one frequency was detected, the receiver's automatic searching program was interrupted. The receiver was subsequently connected to a directional antenna in order to obtain a better fix for the detected signal. The frequency, location, date and time of day was then recorded on a map of the area. The detected frequency was then deleted from the receiver's memory before re-starting the automatic searching routine.

Initial tracking of the marked sturgeon using a boat proved to be extremely time consuming due to the great distances these fish migrated (>40 km). This procedure was subsequently abandoned. Monitoring of the radio tagged sturgeon and walleye was completed using both a fixed wing aircraft and fixed antennae stations.

b) Aerial Reconnaissance of the Study Area

The positions of the marked lake sturgeon and walleye were monitored monthly from November/88 to March/89, weekly from April to June/89 and monitored biweekly from July to October/89. The flight plan for the aircraft initiated north from Whist Falls on the Groundhog River, past the confluence of the Groundhog and Mattagami Rivers, and north along the Mattagami River to Grand Rapids. A second sweep began 10 km north of the Mattagami River, journeyed the entire length of Adam Creek to the forebay of Little Long GS and then upstream on the Mattagami to Cypress Falls. The flight plan included the entire proposed hydroelectric extensions on the Mattagami River. The automatic searching program was similar to that described for the boat. A similar flight plan was followed in 1990, but only for the tracking of lake sturgeon.

The aircraft was outfitted with two loop, independently operated antennae (one vertical and one horizontal), one per wing, which had been tuned to the 50 MHz band (tuned by Ministry of Natural Resources). The independence of these antennae allowed for the switching between wings, and therefore aided in locating the position of the tagged fish. The aircraft maintained a search altitude of approximately 200 m and a speed of 120 knots during all flight

plans. Initial scanning interval for each targeted frequency averaged three seconds.

The error associated with the location of known radio signals using the aircraft was estimated to be a plus or minus 150 m. This error was determined by having the individuals in the aircraft fix the location of a hidden reference transmitter. This error estimate was determined under ice free conditions at water temperatures at 5 and 10°C.

All detected signals (frequencies) from the aerial reconnaissance were placed on a map of the area (scale 1:50000). Their locations were recorded in Universal Transverse Mercator units (UTM).

c) Fixed Antennae - Stations 1 - 9

The movement or presence of any of the radio tagged lake sturgeon and/or walleye within defined sections of the study area, prior to, during and following spring freshet, was also continuously monitored from four fixed stations in 1989 and from five locations in 1990. Each of these stations was equipped with a four element, 2.5 m^2 Yagi fixed on a 6.5 m television tower. The location of each of these stations is shown in Figures 3a - h.

Station 1 (1989) was located close to the mouth of Adam Creek, approximately 2.5 km south of the Mattagami River. This station was programmed to monitor the movement of sturgeon (n=12) tagged in the vicinity of Kipling GS, the 3 tagged at the north falls on Adam Creek and the six individuals tagged just below the control structure on Adam Creek. In addition, this station also determined the presence of any of the radio tagged walleye (n=15) in Adam Creek.

Station 2 (1989) was located just north of the control structure on Adam Creek. This station was programmed to monitor the potential passage of any tagged sturgeon (n=19) from Little Long headpond into Adam Creek. The station also kept track of the six tagged sturgeon just below the diversion channel's control structure.

Station 3 (1989) was located at the interface of the Mattagami River and the forebay of Little Long GS. This station was programmed to record the possible entry or exit of any radio tagged sturgeon from the forebay.

Station 4 (1989) was located at the confluence of the power and spill canals of Little Long GS. This station determined the potential passage of any radio tagged sturgeon from the forebay and through the dam at Little Long GS.

Station 5 (1990) was located on the south end of the third island approximately 3 km north of Kipling GS tailrace. This station was programmed to monitor the presence of sturgeon (n=12), initially radio tagged in the vicinity of Kipling GS, in the area immediately north of island where

potential spawning habitat for lake sturgeon had been suggested (B. Parker, *pers. comm.*)

Station 6 (1990) was located at the mouth of Adam Creek. This station was programmed to monitor the presence of lake sturgeon at the mouth of the creek, but not in the creek, prior to, during and following freshet. Again, this area had been suggested as representing potential spawning habitat for lake sturgeon (B. Parker, *pers. comm.*).

Station 7, 8, and 9 (all - 1990) were located south of the forebay of Little Long GS. These stations were designed to monitor the presence or passage of the 29 radio-tagged lake sturgeon prior to, during and following freshet.

Each station's antenna was calibrated and tuned to the radio frequencies according to the procedure outlined in OHRD Report C88-108-K. The gain at each of the stations was adjusted to the environmental background noise. In addition, qualified individuals from LOTEK ENG Ltd. were employed to check on the positioning and setup of each station.

The maximum coverage provided by each station was determined by manually positioning reference transmitters at various distances until the signal was no longer being recorded at the station by the radio receiver. The calibration check for each station was conducted at an average depth of 4 m. The exception was the spillway pools north of Adam Creek control structure where the depth averaged 2 m. The coverage provided by each station is displayed in Figures 3a - h.

Connected to the antenna of each station was a programmable radio receiver. These receivers automatically scanned each programmed frequency at a pre-selected interval (4 s). Data was stored on an hourly basis. A data acquisition unit was connected to each of these receivers and stored all detected signals by date and time of day. Receivers were powered from two, twelve volt lead-acid batteries. Data from these receivers were manually transferred to a computer at two-week intervals (*i.e.* 12-day blocks) for analyses.

2.5 Data Analyses

The distribution of all radio tagged fish, as located using aircraft, was graphically displayed indicating the general direction (north or south) and distance traveled (km) relative to the original release position. The data displayed encompassed the period prior to, during and following spring freshet. These graphs are intended to illustrate the extent of the migratory movement for the two species relative to freshet.

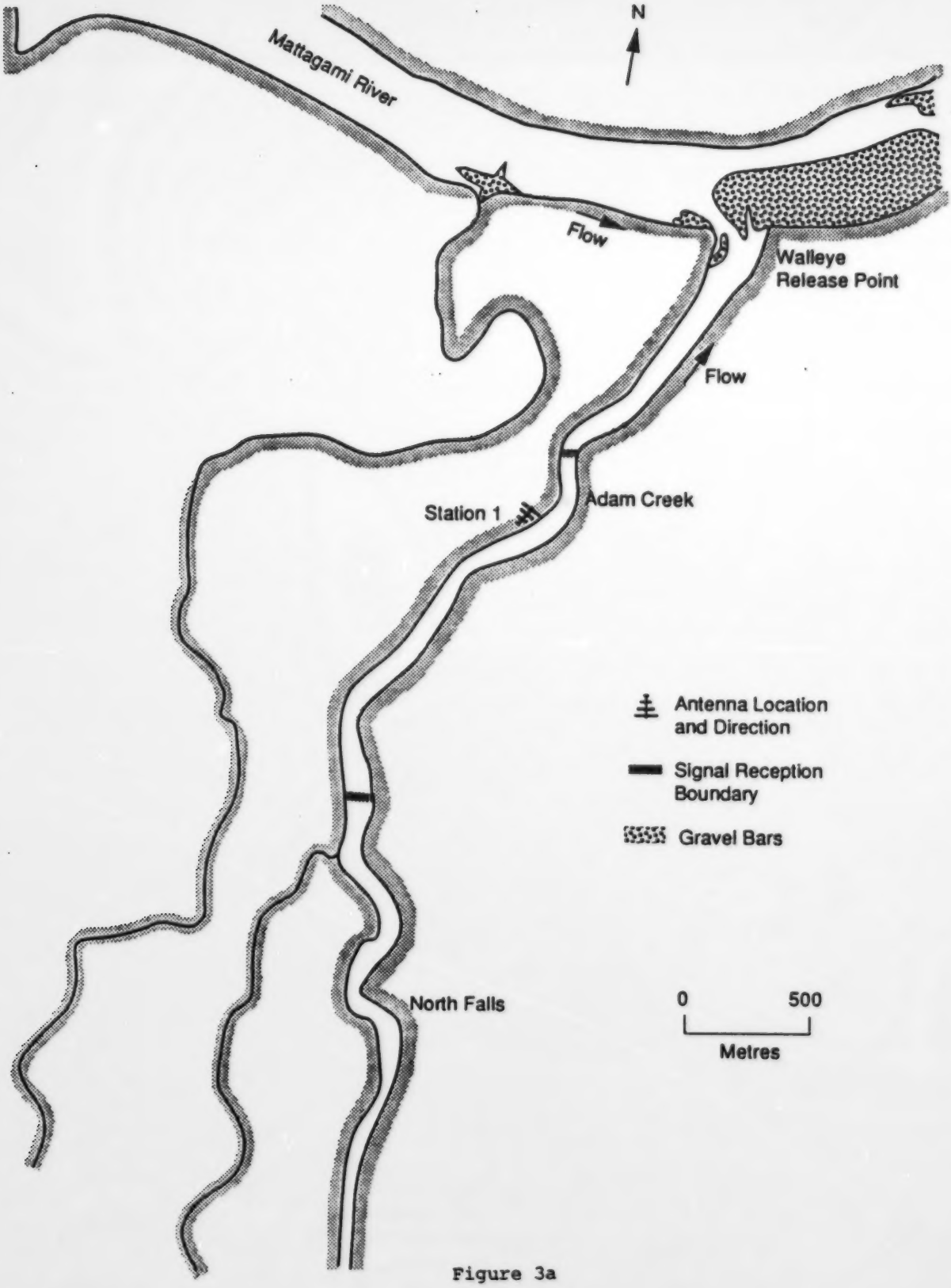


Figure 3a

MATTAGAMI RIVER FIXED RADIO TELEMETRY RECEIVING STATIONS, 1989

91-104
181807-L10-RD

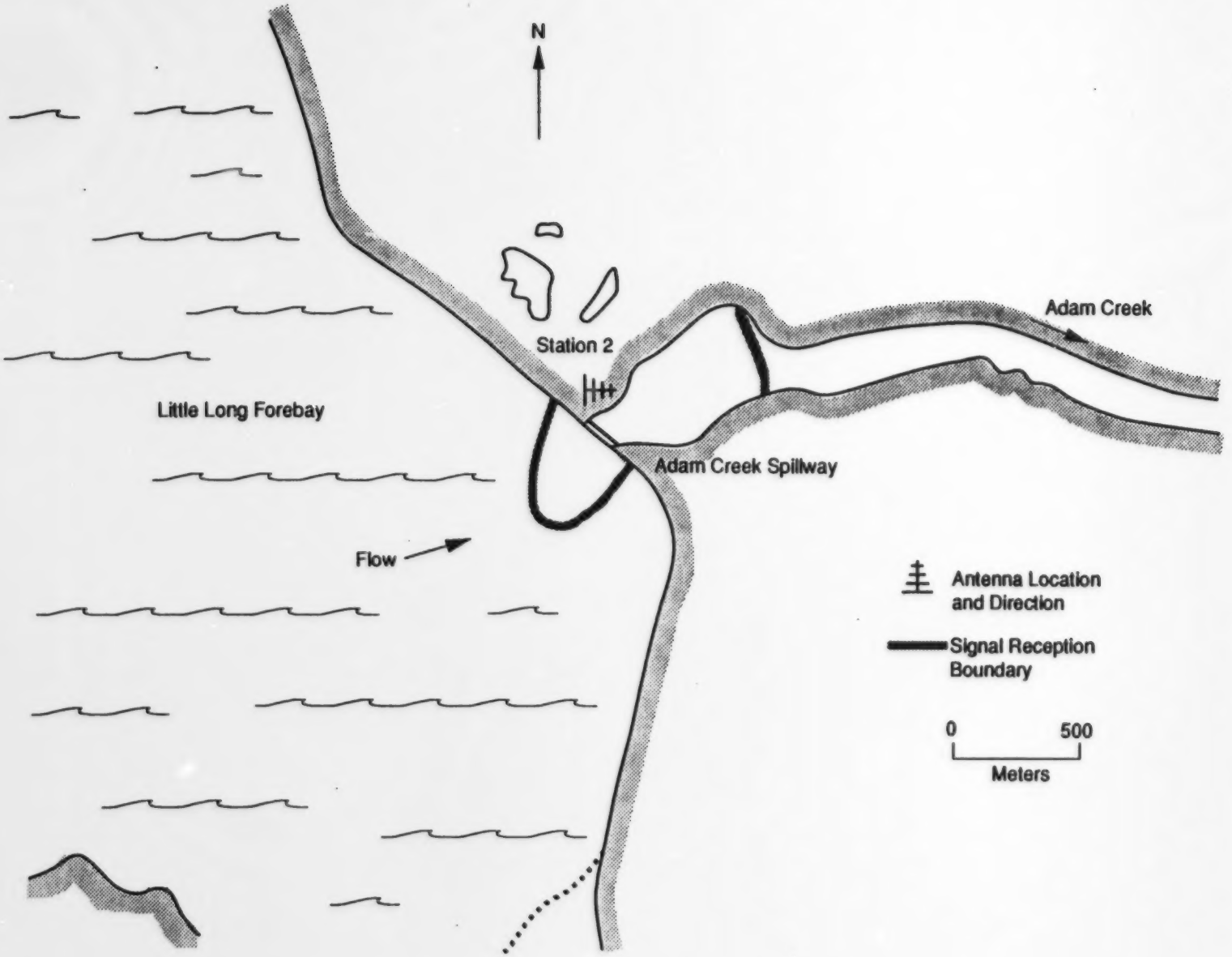


Figure 3b

MATTAGAMI RIVER FIXED RADIO TELEMETRY RECEIVING STATIONS, 1989

91-104
181808-L10-RD

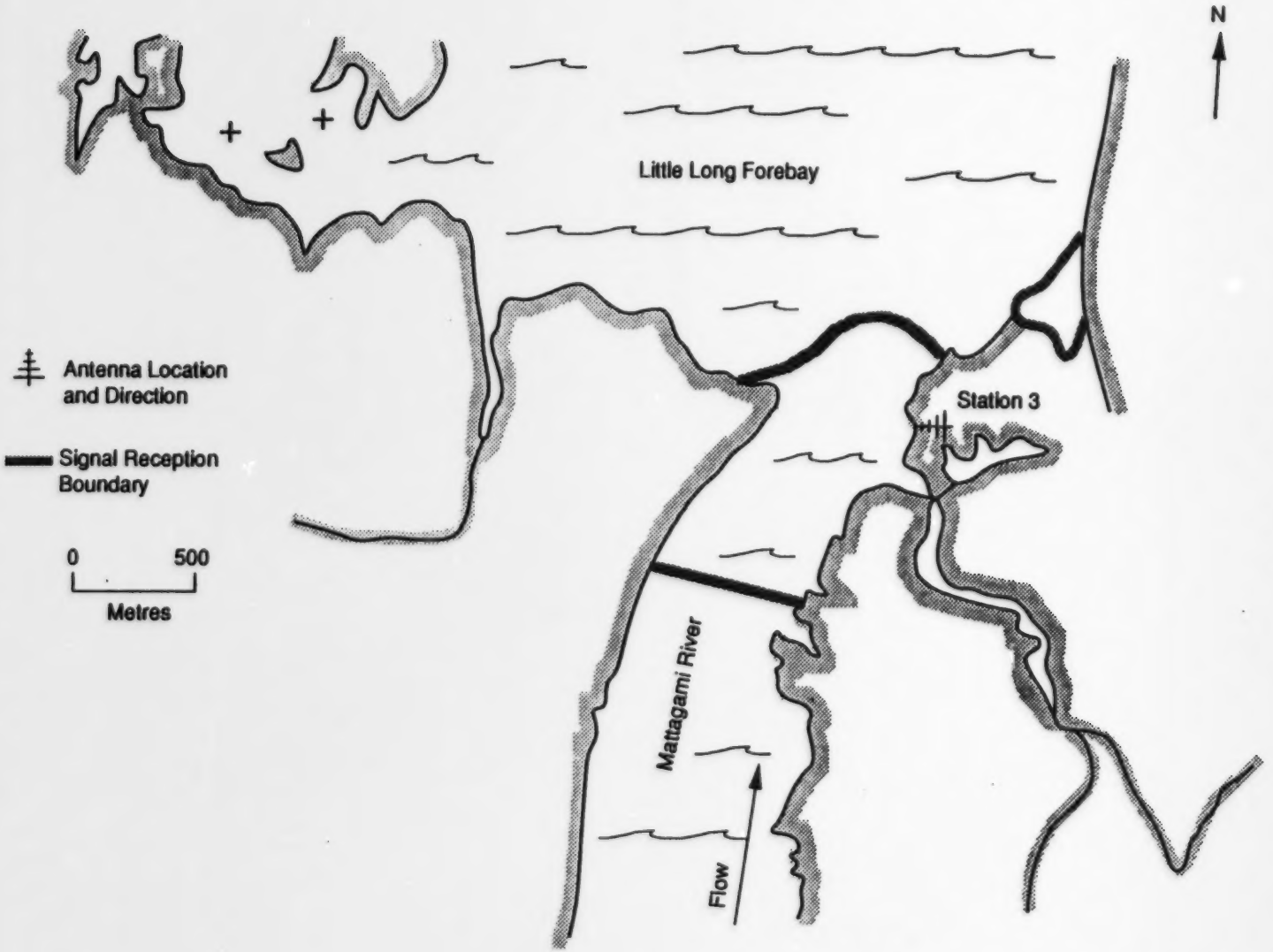


Figure 3c

MATTAGAMI RIVER FIXED RADIO TELEMETRY RECEIVING STATIONS, 1989

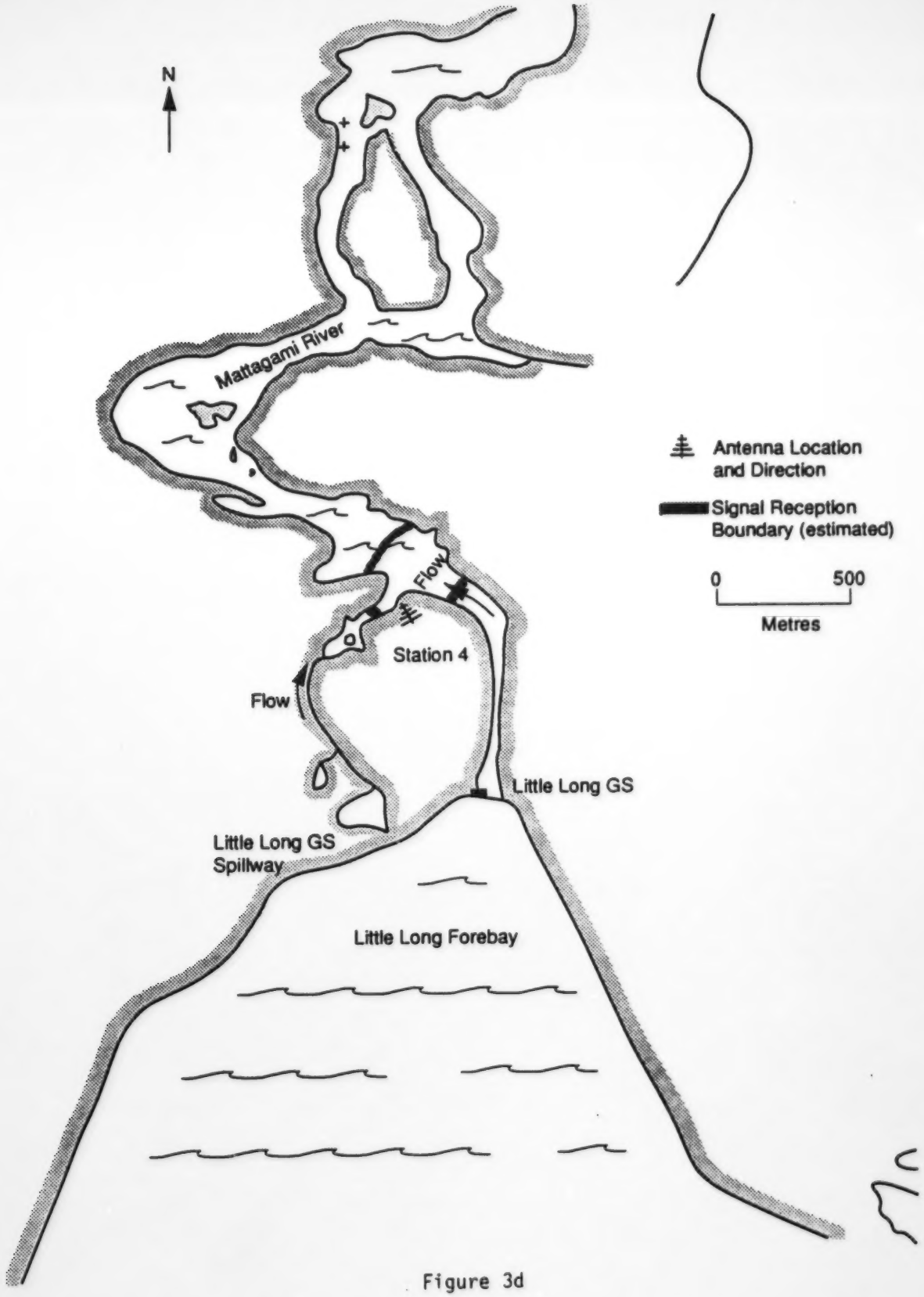


Figure 3d

MATTAGAMI RIVER FIXED RADIO TELEMETRY RECEIVING STATIONS, 1989

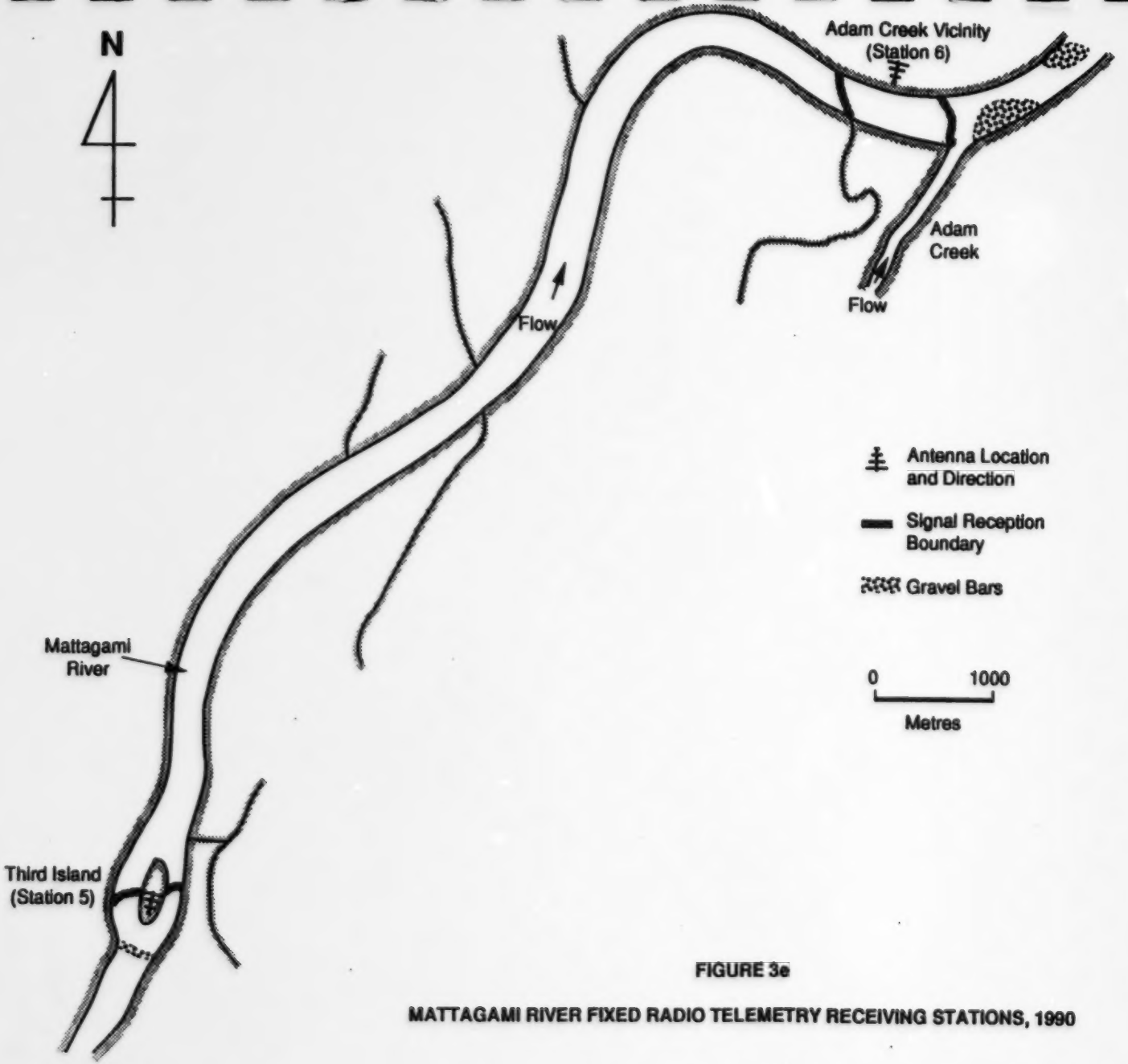


FIGURE 3e

MATTAGAMI RIVER FIXED RADIO TELEMETRY RECEIVING STATIONS, 1990

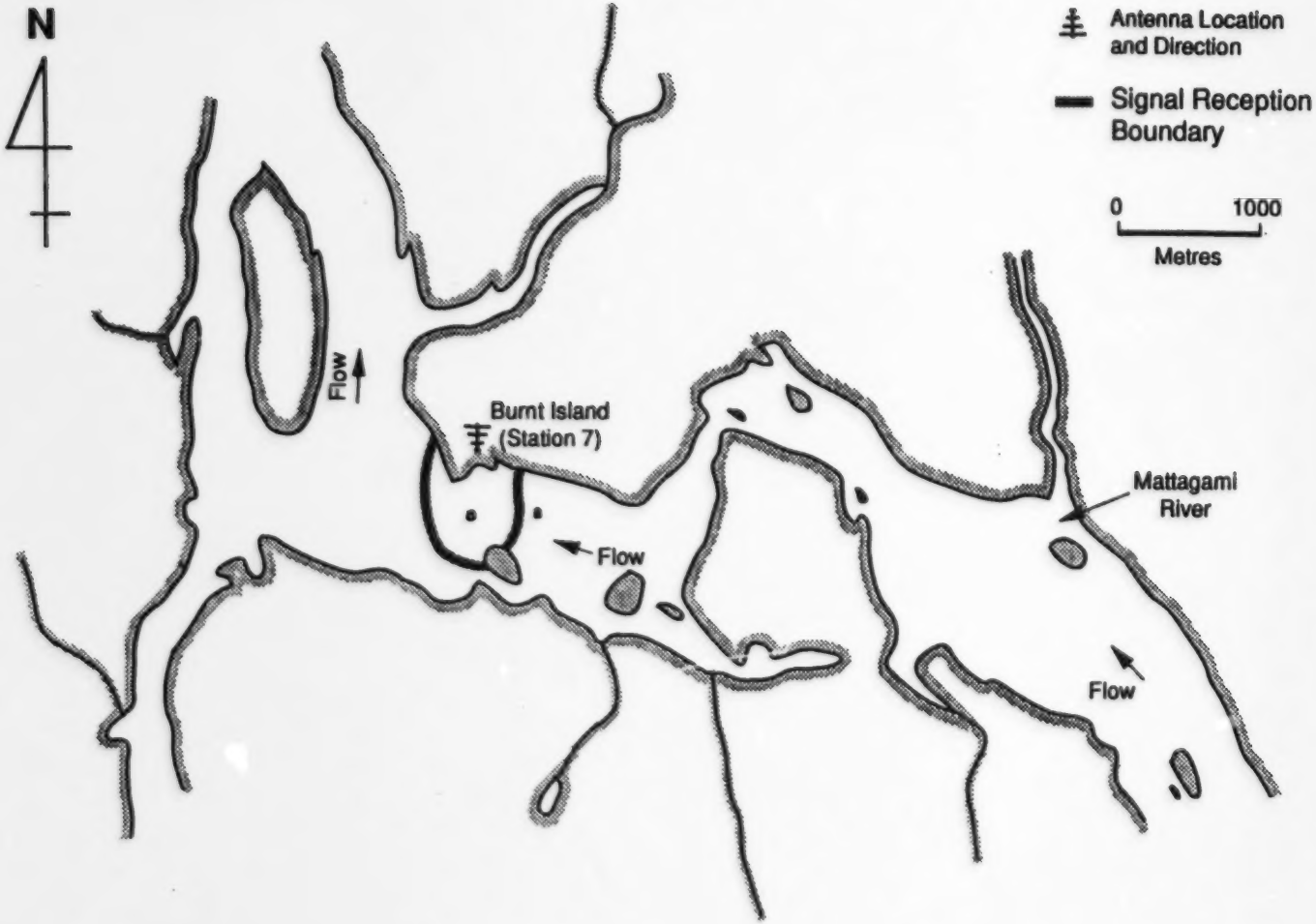


FIGURE 3f

MATTAGAMI RIVER FIXED RADIO TELEMETRY RECEIVING STATIONS, 1990

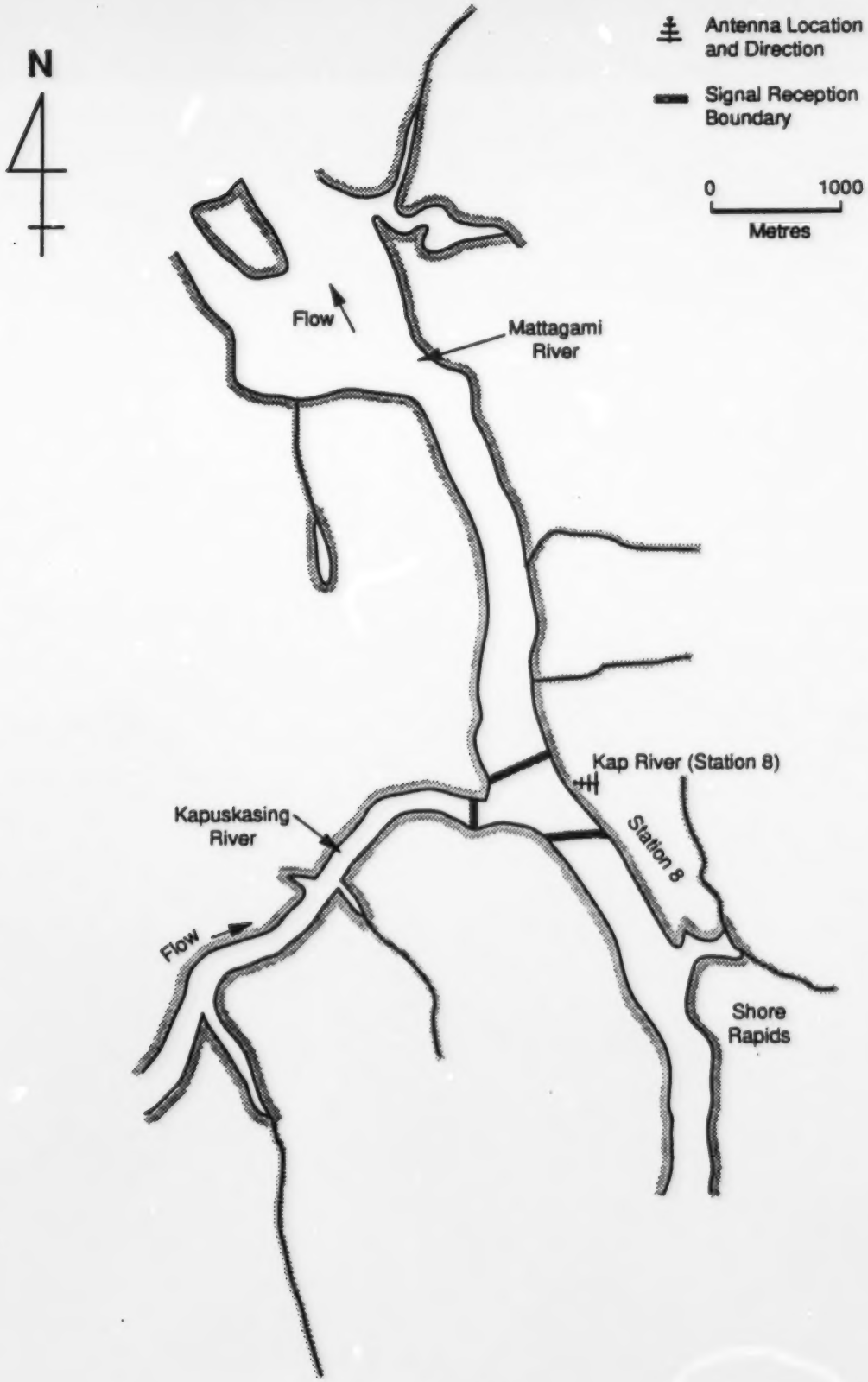


FIGURE 3g

MATTAGAMI RIVER FIXED RADIO TELEMETRY RECEIVING STATIONS, 1990

184881-S51-RD
91-104

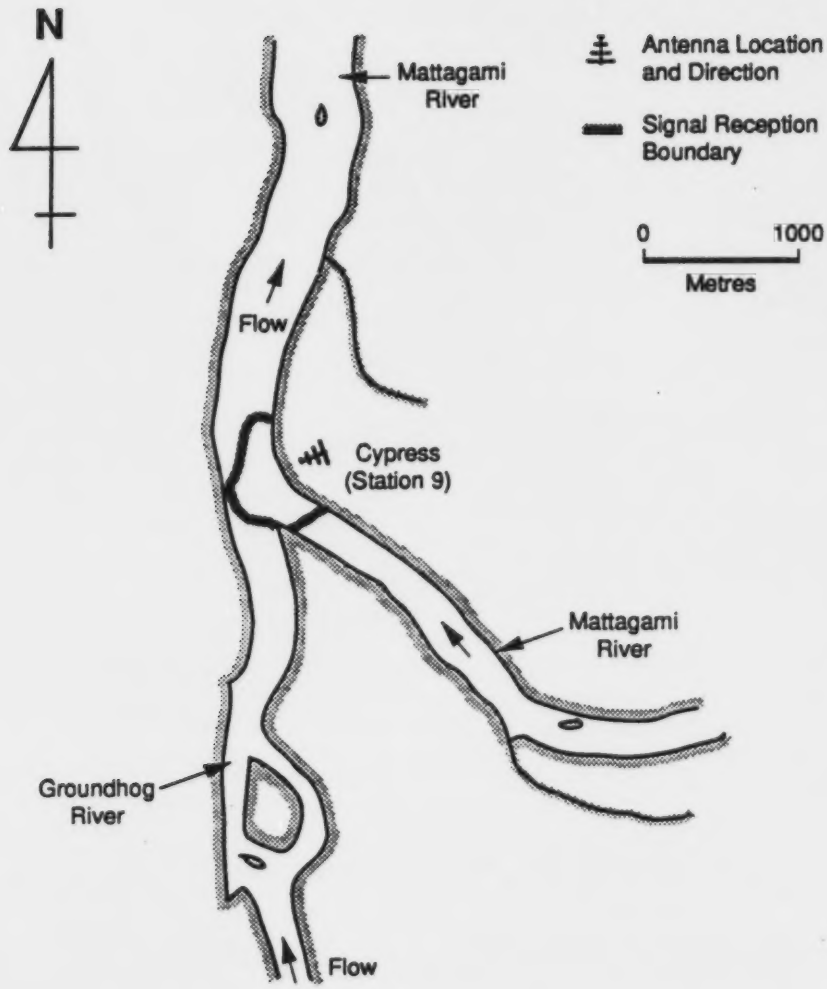


FIGURE 3h

MATTAGAMI RIVER FIXED RADIO TELEMETRY RECEIVING STATIONS, 1990

Data from the fixed stations were graphically displayed as the total number of occurrences of radio tagged fish recorded over a twenty-four hour interval for the pre-freshet, during freshet and post-freshet periods. The occurrences of sturgeon and walleye at Station 1 in Adam Creek were separated and individually displayed. Because the occurrences of either sturgeon or walleye are recorded over a 24 h period, these graphs also display an indirect measure of diurnal activity.

Data were summarized and presented over eight, 12-day periods only for the purpose of graphical presentation.

3. RESULTS

3.1 Meristics

Both experimental and sturgeon gill nets were employed in 1989 and 1990. Experimental gill nets were used to collect adult walleye in the tailrace of Kipling GS (1989) and for the capture of juvenile sturgeon (for radio tagging).

Of the five walleye (3 males/2 females) collected in the middle of May (May 16-17, 1989), only the males were ripe (running). The two females were spent (only a few eggs remaining).

Of the fifteen radio tagged walleye (fall, 1989), only one third of them could be sexed prior to suturing. Tags 102 and 103 were female whereas tags 104, 114 and 116 were males.

The twenty-two, 24 h sturgeon sets in 1989 yielded a total of 116 individuals. All the individuals were captured alive. The average weight and length (fork) of these fish were 5.1 kg and 80 cm, respectively. Of the few individuals (11) sacrificed for sex determination and spawning condition, males outnumbered females by an approximately three to one ratio. The average weight for males was 3.5 kg. Females averaged 4.7 kg. One of the sacrificed males and females exhibited ripe gonads. The gonadal condition for the other sacrificed sturgeon could not be determined. The ripe fish were collected west of Cypress Falls in the middle of May/89.

In 1990, only thirteen 24 h sturgeon sets were employed. These sets yielded a total of 114 adult sturgeon. The increase in catch/unit effort in 1990 as opposed to 1989 was attributable to fishing efforts at Cypress Falls in May. At that time, adult sturgeon had congregated at the Falls to spawn and therefore were easily netted. The weights of males and females were similar to those collected in 1989. As in 1989, the males caught far outnumbered the females.

Juvenile sturgeon were only collected, using experimental gill nets, in the immediate vicinity of the confluence of the Groundhog and Mattagami Rivers and Cypress Falls. Juvenile sturgeon were not collected in any of the other areas systematically fished south of the confluence of the two rivers, including Little Long GS forebay. All juveniles collected were alive. The occurrence and successful capture of juvenile sturgeon at the confluence of the Mattagami and Groundhog Rivers has also been reported by Beamish (1990).

3.2 Movement of Walleye and Lake Sturgeon

3.2.1 Aerial Reconnaissance

3.2.1.1 Walleye

Approximately 73 per cent of the radio tagged walleye (n=11) were successfully located for the majority of the reconnaissance flights (Figures 4a, b, & c). Differences in distance or direction travelled between the two females and three males were not evident. Any appreciable movement (>1 km) was restricted to the period of April to July. Six of the eleven walleye located initially traveled north (downstream). The majority (4) of these individuals traveled greater than 22 km and were located beyond Grand Rapids. The remaining five individuals remained within 15 km of the mouth of Adam Creek. All reversed direction (*i.e.* upstream) at the initiation of freshet (Figures 4b & c).

3.2.1.2 Sturgeon (Adults)

Greater than 75 per cent of the radio tagged sturgeon (n=14) tagged north of Kipling GS were located for the majority of the aerial reconnaissance flights (Figures 5a, b, c & d). At least 50% of these individuals inhabited a 30 m deep basin situated below the stations' spill structure. Generally, the presence/absence of these individuals in the vicinity of the stations tailrace was not influenced by the freshet period. Three of the radio tagged sturgeon traveled greater than 22 km and were located beyond Grand Rapids in early April (Figure 5c). The majority of the sturgeon however inhabited a 30 m deep pool, located immediately downstream from the Kipling GS.

All radio tagged sturgeon released in pools just north of the Adam Creek Control Structure (6 - 1989, 5 - 1990) were recorded during each aerial reconnaissance flight (Figure 6). The initiation of spilling from the control structures (freshet) coincided with the northerly displacement of three of these individuals in 1989. A similar trend was noted in 1990 but by more individuals and at a later date in the spilling event. All fish did however return to their original release position following freshet.

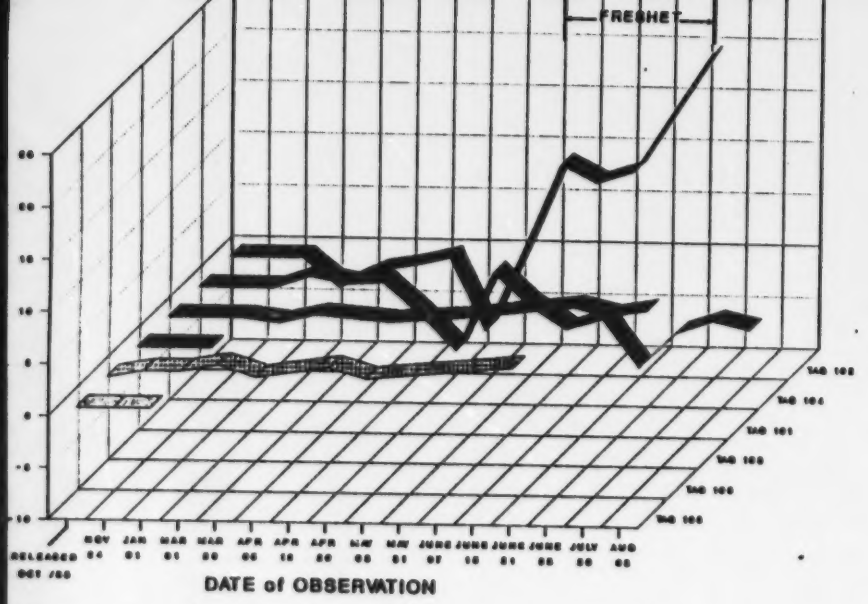


FIGURE 4a

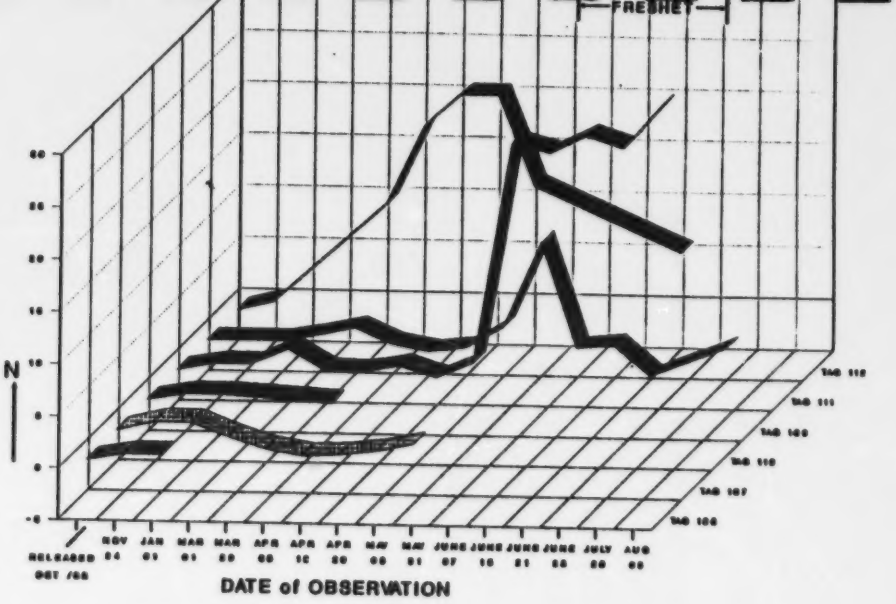


FIGURE 4b

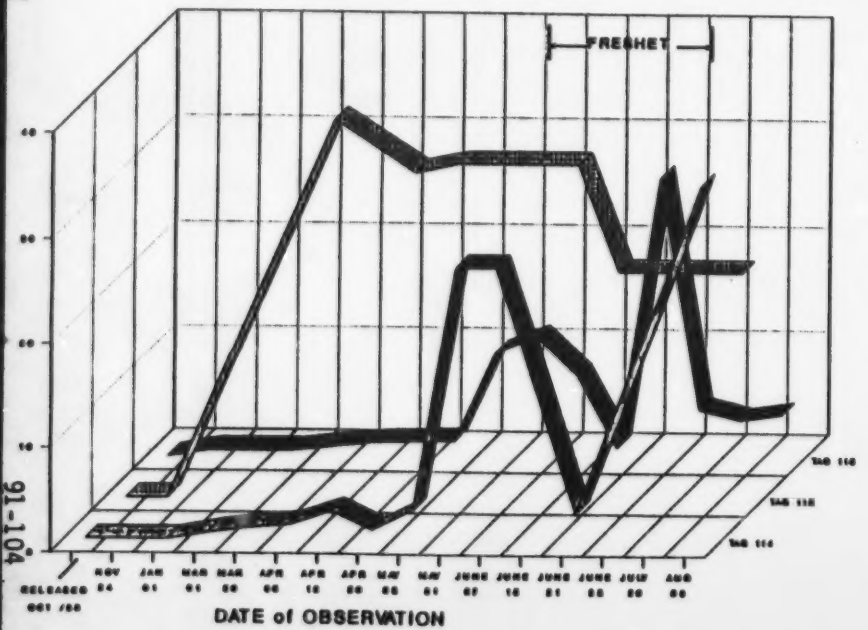


FIGURE 4c

FIGURE 4 a,b,c

General direction and distance travelled relative to the original release position for walleye (15) tagged at the mouth of Adam Creek. Data has been derived from aerial reconnaissance flights. The dates of observations are from November to August 1989

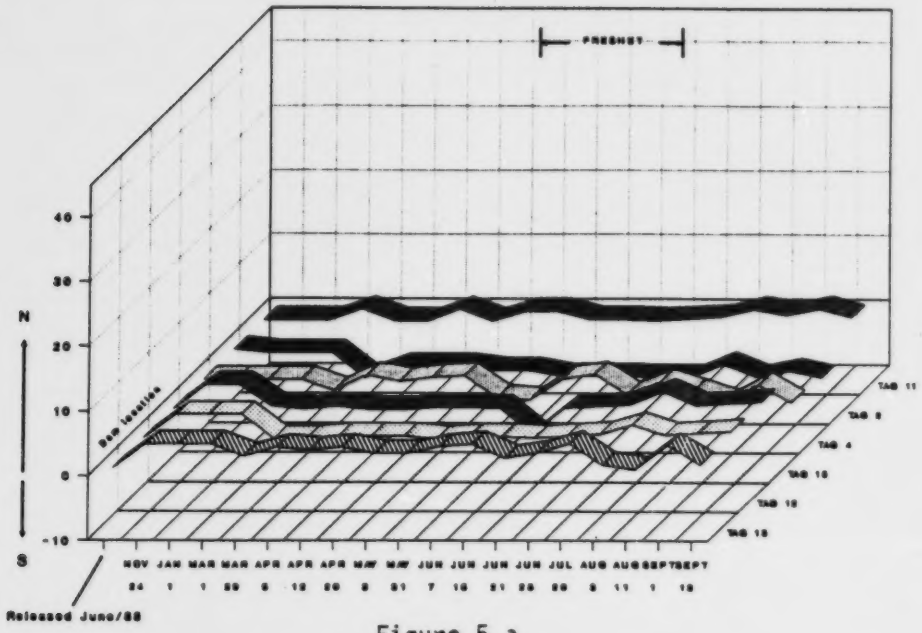


Figure 5 a

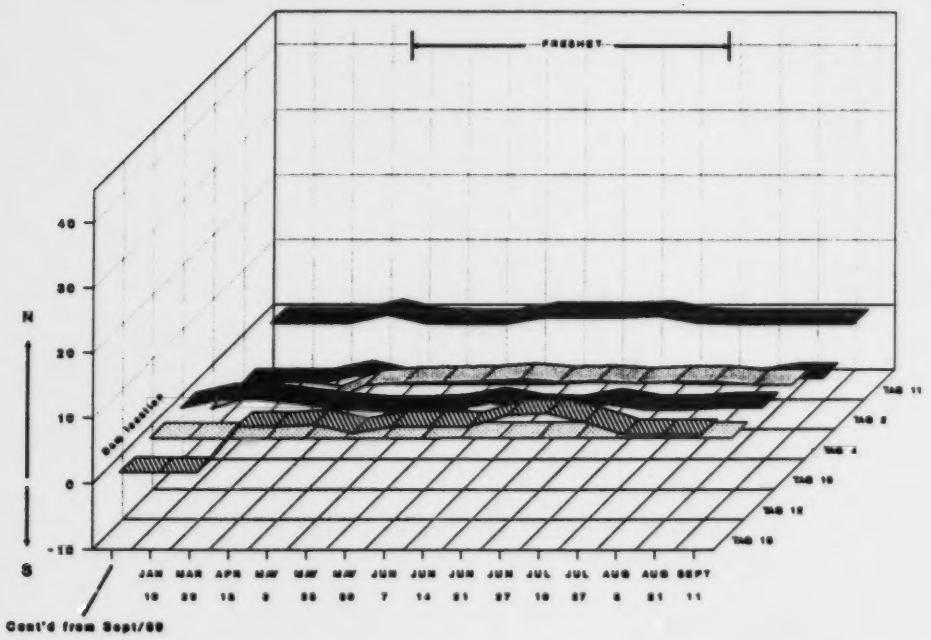


Figure 5b

General direction and distance travelled relative to the original position for lake sturgeon (12) detected in the vicinity of Kipling GS tailrace. Data has been derived from aerial reconnaissance flights. The dates of observations are from June 1988 to September 1990

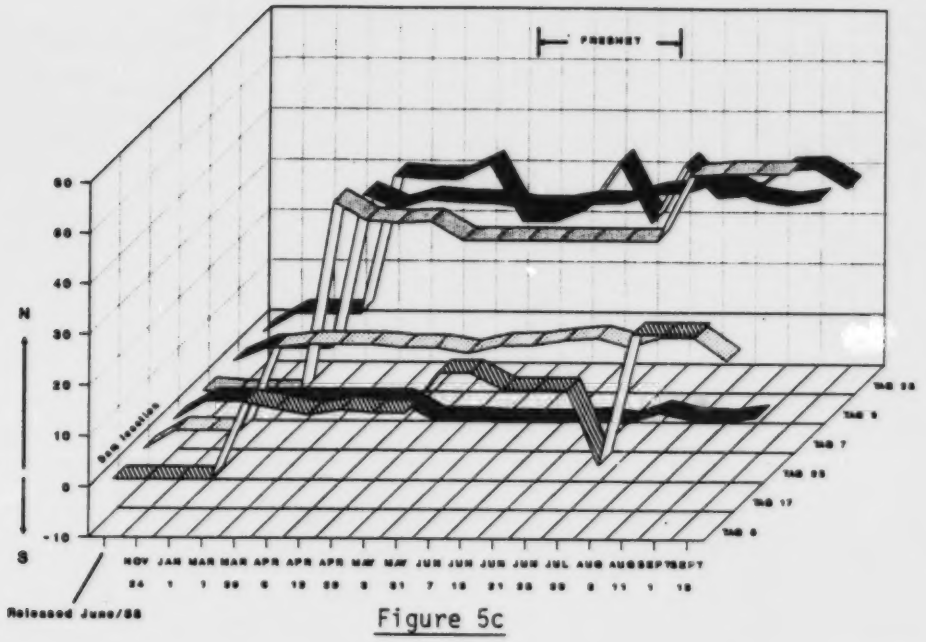


Figure 5c

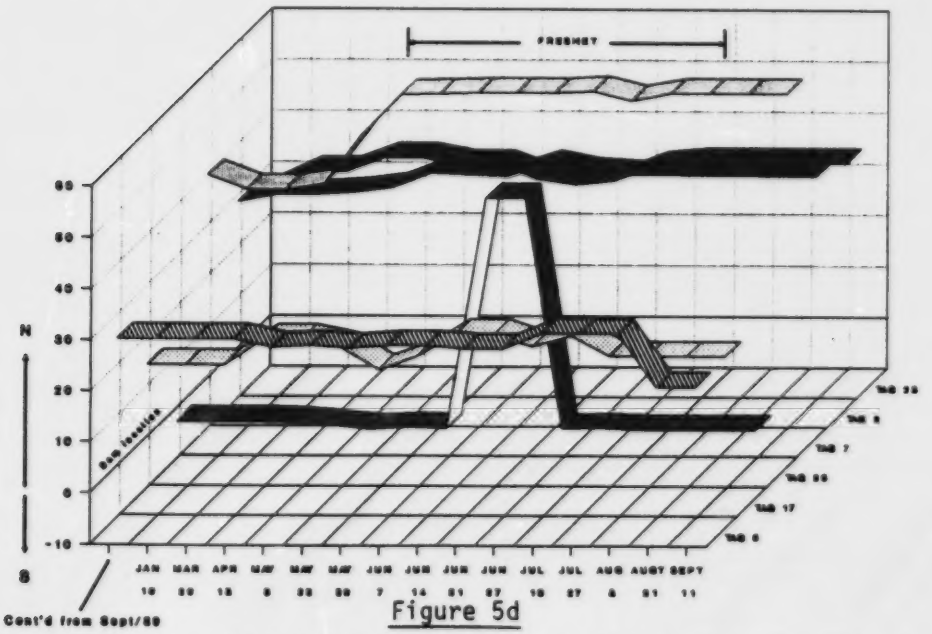


Figure 5d

General direction and distance travelled relative to the original position for lake sturgeon (12) detected in the vicinity of Kipling GS tailrace. Data has been derived from aerial reconnaissance flights. The dates of observations are from June 1988 to September 1990

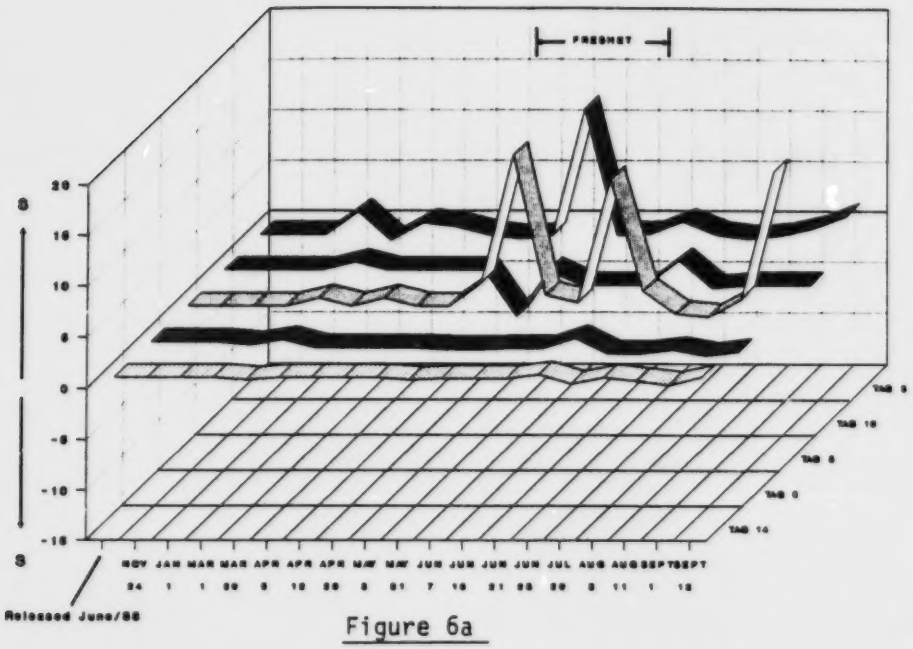


Figure 6a

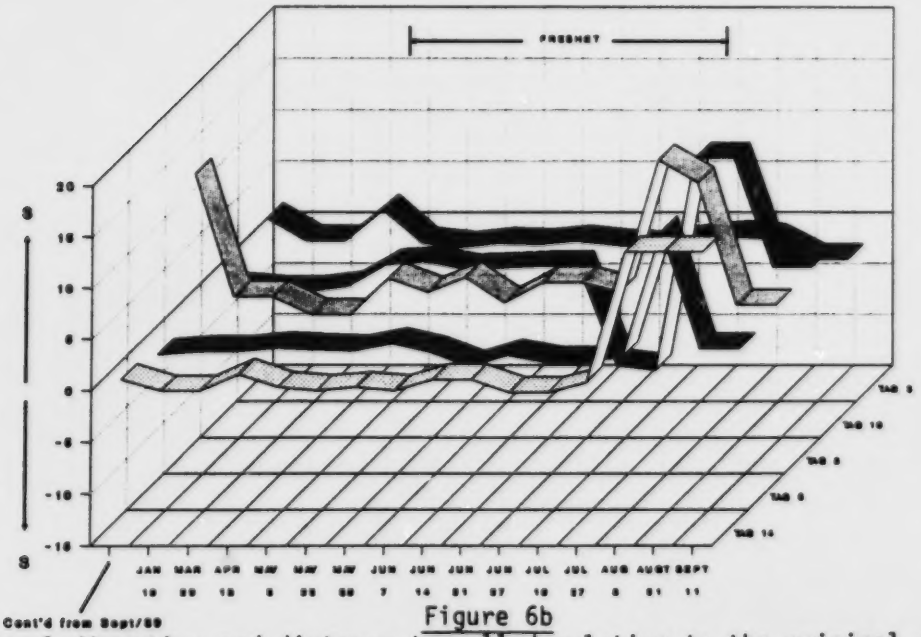


Figure 6b

General direction and distance travelled relative to the original position for lake sturgeon (5) detected in the vicinity of the Adam Creek control structure. Data has been derived from aerial reconnaissance flights. The dates of observations are from November 1989 to September 1990.

Only one of the three radio tagged sturgeon released at the North Falls on Adam Creek were located during the initial two aerial reconnaissance flights (1989). In 1990, two of these individuals were located approximately 20 km north of Adam Creek during freshet. One of the original three tagged in 1989 was not found in 1990 (Figure 7a,b).

Seventy-five per cent of the 29 radio tagged sturgeon released just south of Little Long GS forebay were successfully located during the two years of aerial reconnaissance flights (Figures 8 a, b, c, d, e, & f). Only one of the original 19 marked sturgeon journeyed north into the forebay after being tagged and released. This individual was never located outside the forebay during any of the subsequent flights and during the fall of 1989 was located in the forebay of Smoky GS. The majority of the radio tagged sturgeon traveled approximately 30 km south (upstream) from their original release position of 3 km south of the forebay. These fish remained in the Groundhog River or at the confluence of the Groundhog and Mattagami Rivers throughout most of the flights. Little if any activity in movement by these individuals coincided with freshet or the spilling period at Adam Creek. In 1990, two of the original 19 entered the forebay during freshet. These individuals reversed course and left the forebay well before the end of freshet.

The ten adults outfitted with temperature sensing tags in the fall of 1989 were found approximately 30 km south of the forebay prior to freshet in 1990 (Figure 9). The majority of these fish did journey south towards the forebay at the initiation of freshet. All but one individual reversed direction prior to the end of freshet. Initial movement of sturgeon coincided with a water temperature of approximately $8^{o}C$.

3.2.1.3 Sturgeon (Juveniles)

Preliminary analyses of late fall and early winter reconnaissance flights suggested that juvenile sturgeon do not move to the same extent as adults (Figure 10). To date, all radio tagged sturgeon were found within 7 km of the confluence of the Groundhog and Mattagami Rivers (their capture and release locations).

3.2.2 Fixed Antennae Stations

Station 1, 1989 - Mouth of Adam Creek, 2.5 km upstream

All fifteen radio tagged walleye were recorded as present sometime during the two 12-day monitoring periods prior to spilling (Figure 11). These individuals were also recorded present sometime during the first three of four 12-day monitoring periods during spilling. None of the marked fish were present during the final 12 days of the freshet. All tagged walleye did however return during the second 12-day period of post-spill.

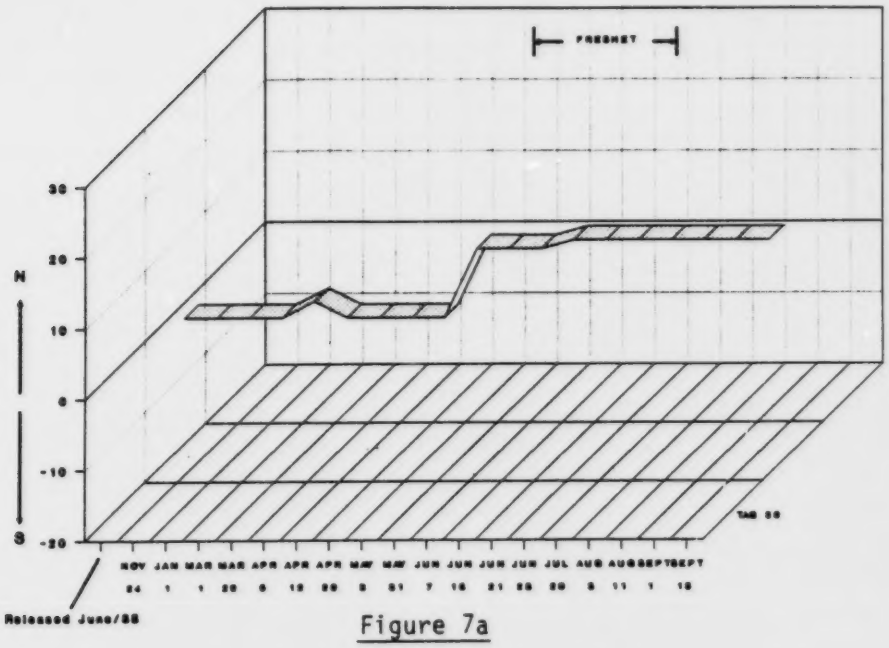


Figure 7a

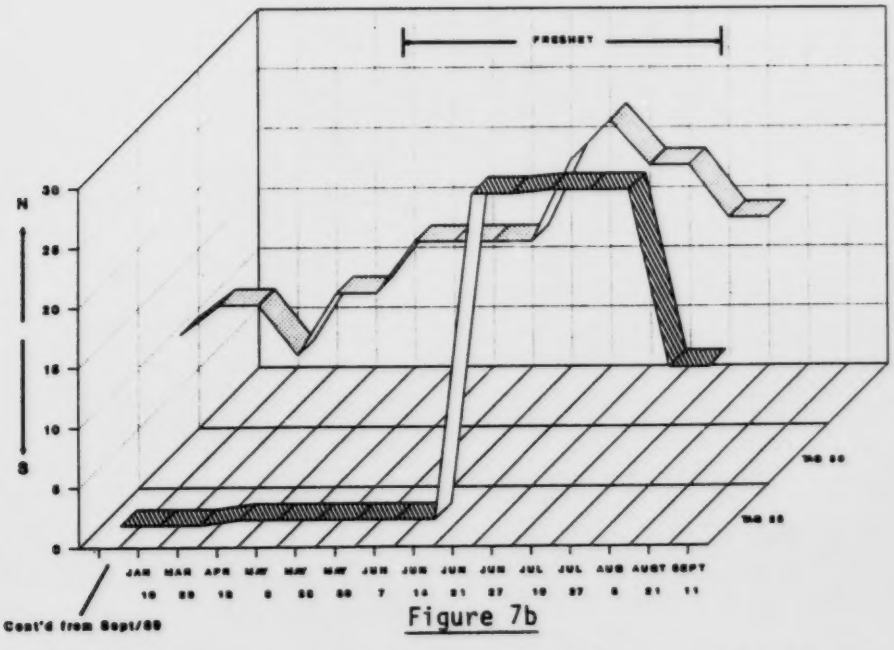


Figure 7b

General direction and distance travelled relative to the original position for lake sturgeon (2) detected in the vicinity of the Adam Creek North Falls. Data has been derived from aerial reconnaissance flights. The dates of observation are from November 1988 to September 1990.

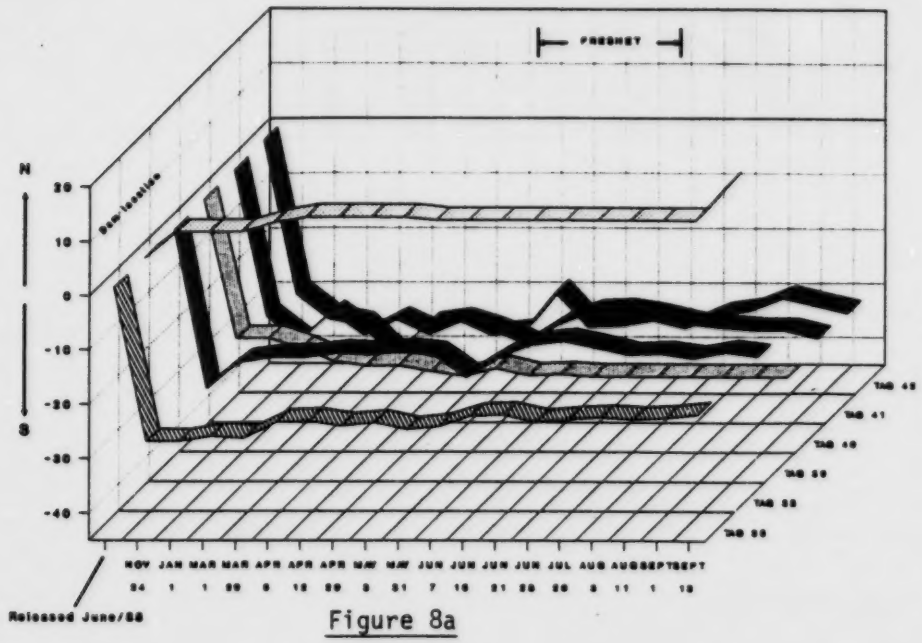


Figure 8a

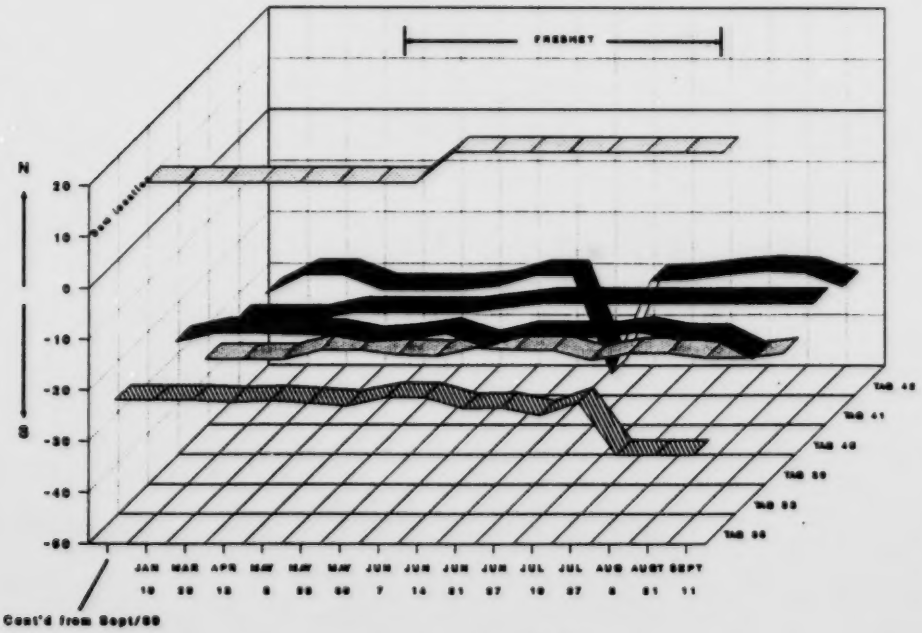


Figure 8b

General direction and distance travelled relative to the original position for lake sturgeon (18) detected south of Little Long GS forebay. Data has been derived from aerial reconnaissance to flights. The dates of observation are from November 1988 to September 1990.

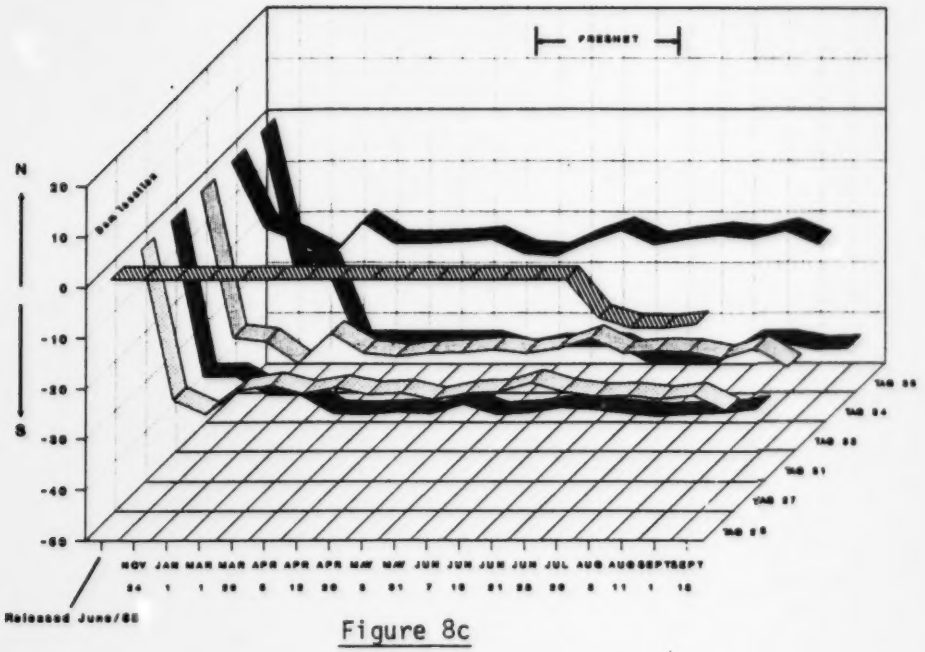


Figure 8c

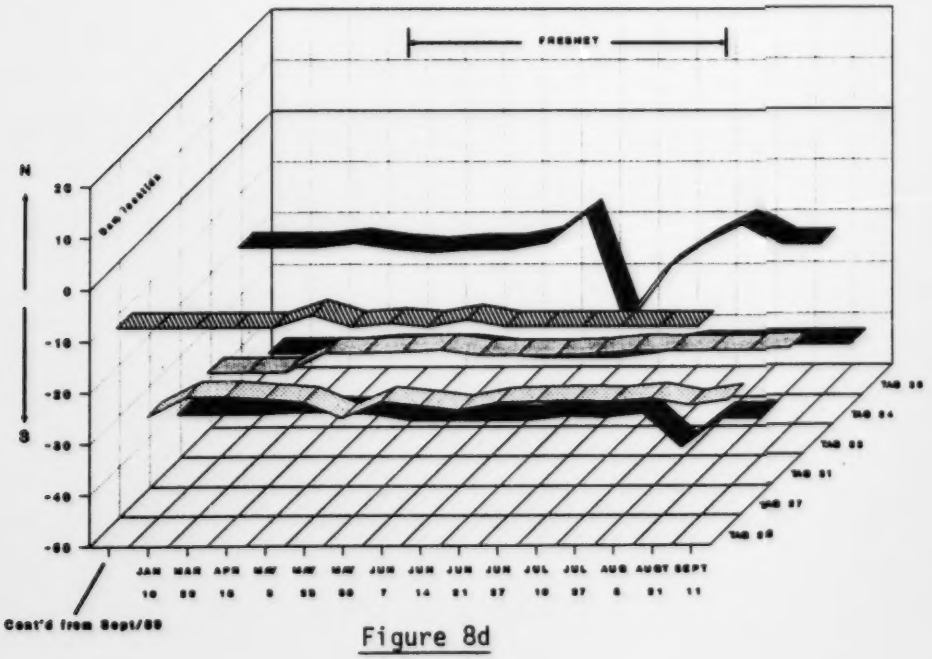


Figure 8d

General direction and distance travelled relative to the original position for lake sturgeon (18) detected south of Little Long GS forebay. Data has been derived from aerial reconnaissance to flights. The dates of observation are from November 1988 to September 1990.

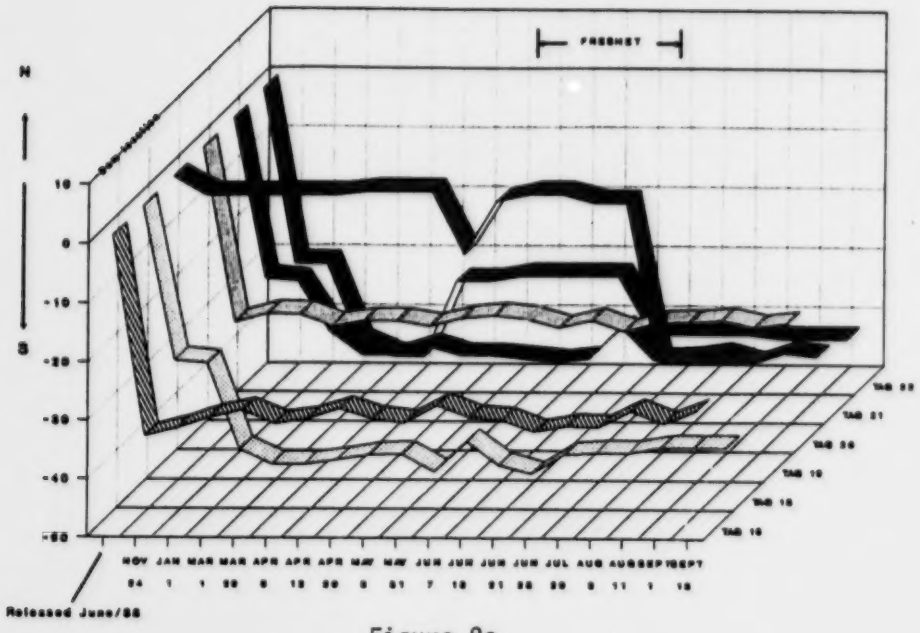


Figure 8e

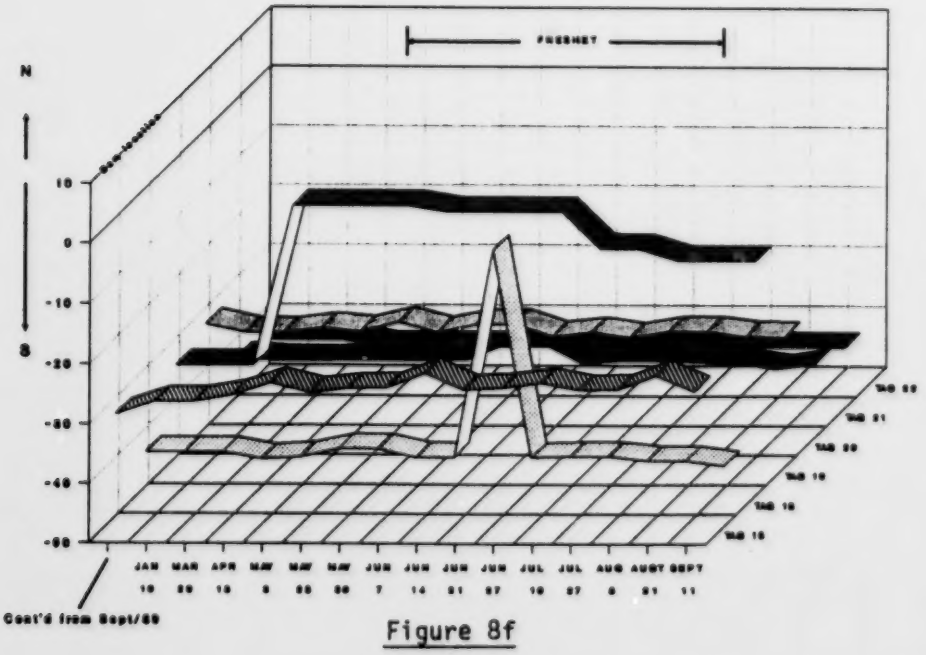


Figure 8f

General direction and distance travelled relative to the original position for lake sturgeon (18) detected south of Little Long GS forebay. Data has been derived from aerial reconnaissance to flights. The dates of observation are from November 1988 to September 1990.

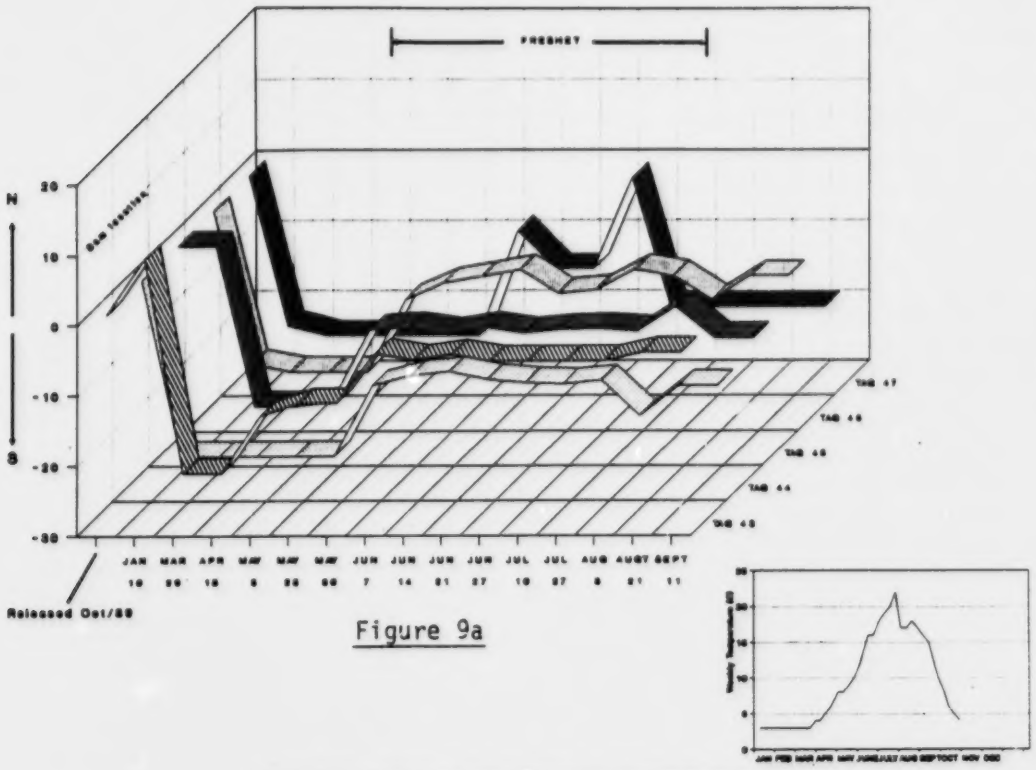


Figure 9a

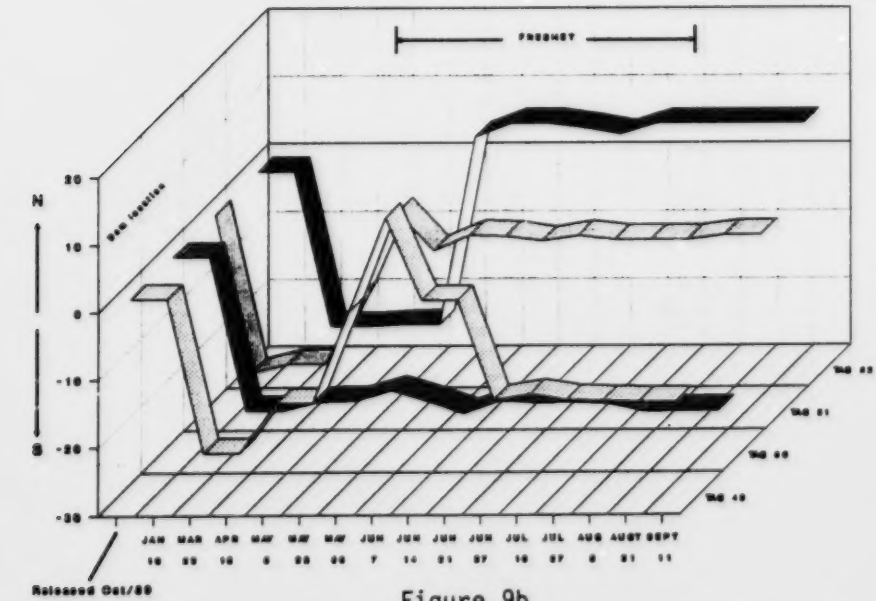
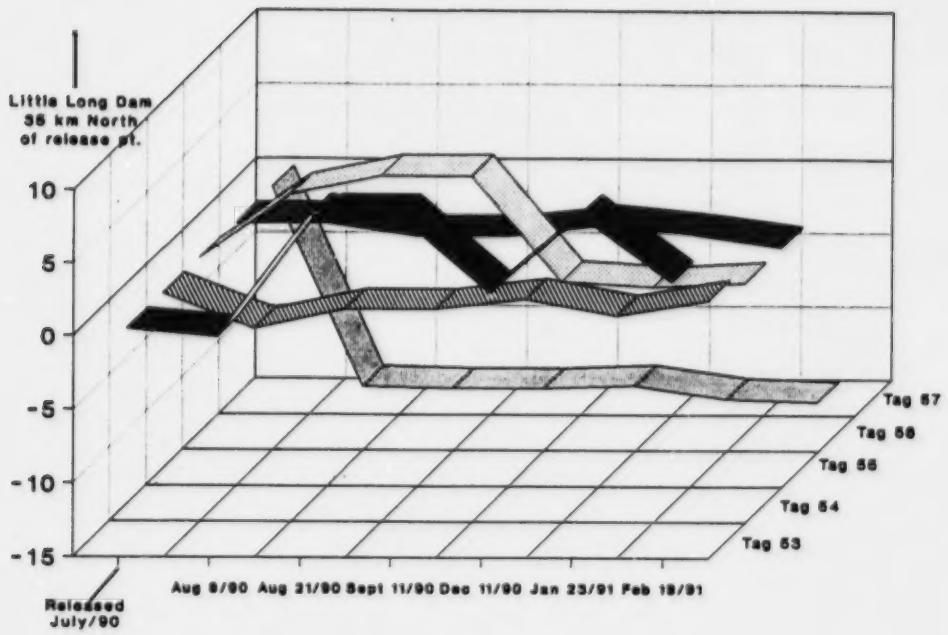


Figure 9b

General direction and distance travelled relative to the original position for lake sturgeon (18) detected south of Little Long GS forebay. Data has been derived from aerial reconnaissance to flights. The dates of observation are from January 1990 to September 1990.



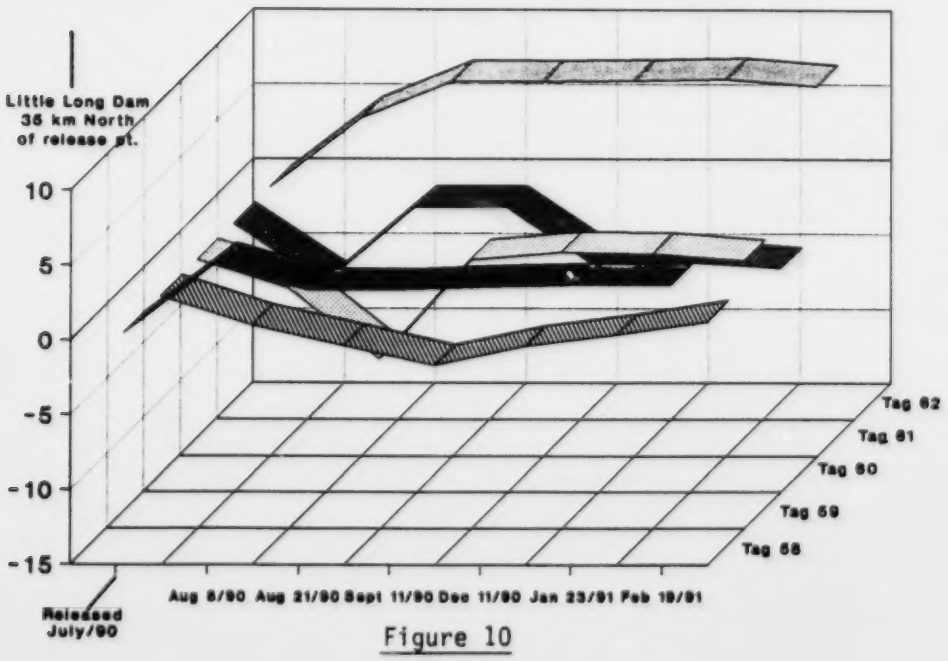


Figure 10

General direction and distance travelled relative to the original position for lake sturgeon (10) detected south of Little Long GS forebay. Data has been derived from aerial reconnaissance to flights. The dates of observation are from August 1990 to February 1991.

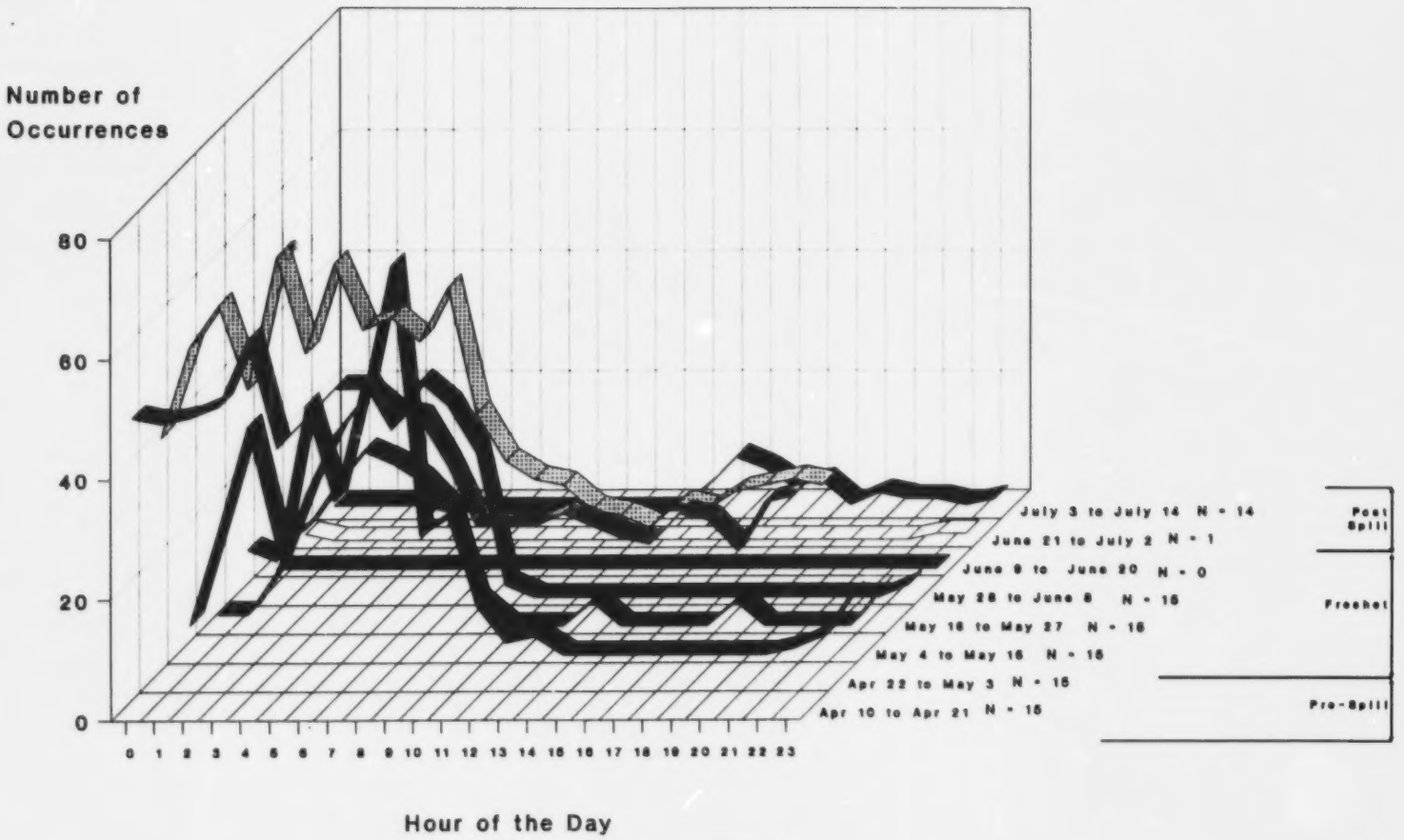

Number of Occurrences
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of the Day
July 3 to July 14 N = 14
June 21 to July 2 N = 1
June 9 to June 20 N = 0
May 28 to June 8 N = 15
May 16 to May 27 N = 15
May 4 to May 15 N = 15
Apr 22 to May 3 N = 15
Apr 10 to Apr 21 N = 15
Post Spill
Freshet
Pre-Spill

Figure 11

Total number of recorded occurrences of radio tagged walleye in the vicinity of the fixed antenna station on Adam Creek. Occurrences were recorded hourly for each fish for 8 consecutive 12d periods (96d).

The number of recorded occurrences of radio tagged walleye in the vicinity of this fixed antenna station prior to and into freshet was greatest between the period of 2400 h and 0800 h. Outside this period, the number of occurrences generally averaged less than 10% of the total number.

This fixed antenna station on Adam Creek also recorded as present all twelve sturgeon radio tagged in the vicinity of Kipling GS tailrace and the three sturgeon radio tagged at the north falls on Adam Creek during the pre-spill monitoring period and for the first three of four 12-day periods of spilling (Figure 12). All but one of these individuals returned during the last post-spill monitoring interval in early July.

The greatest number of recorded observations for lake sturgeon during the pre-spill and spill periods occurred between 2100 h and 0800 h. This time interval accounted for over 90% of all recorded occurrences.

Station 2, 1989 - Immediately downstream from the Adam Creek control structures.

This station recorded the occurrence of the original six sturgeon caught and released in the pools just downstream of the control structures during the spill and post-spill periods (Figure 13). The radio receiver was not operated during the pre-spill period. None of the 19 radio tagged sturgeon from the Little Long GS headpond were recorded as passing through the control structure during the spill period.

Station 3, 1989 - At the interface of the Mattagami River and Little Long GS forebay.

This station did not record the presence of any of the 19 radio tagged sturgeon from the headpond during the pre-spill period (Figure 14). The station did however record a maximum of eight of these individuals passing within range of its antenna during the first half of the spill period. These individuals were generally recorded as present during the early morning and evening hours. Only four of these individuals were present during the post-spill period.

Station 4, 1989 - At the confluence of the spill and power canals of Little Long GS

None of the 19 radio tagged sturgeon from the headpond were recorded as passing through the dam (spillway or station) at Little Long GS. However, aerial reconnaissance indicated that one of the nineteen entered Smoky GS headpond late in the fall of 1989. This fixed station was not operating during this time and therefore could not have recorded the passage of the radio tagged sturgeon.

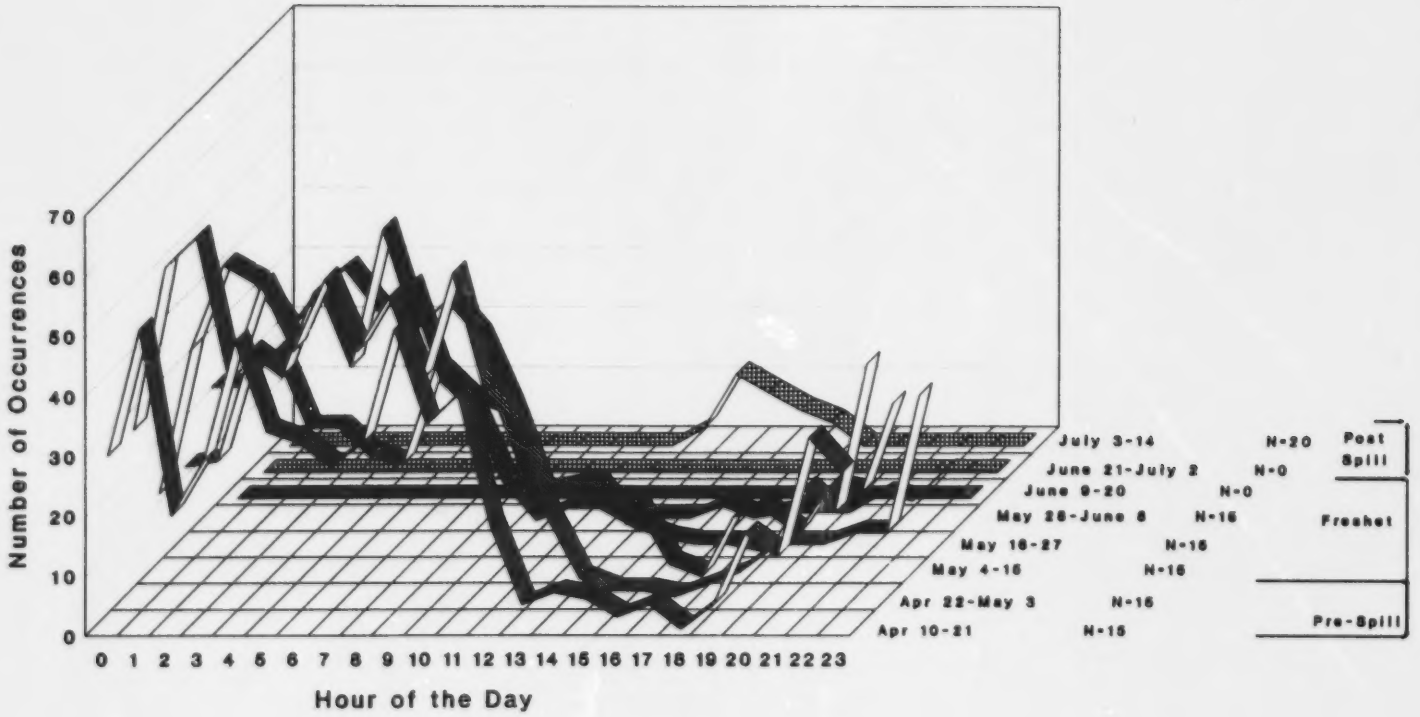


Figure 12

Total number of recorded 1989 occurrences of radio tagged lake sturgeon in the vicinity of the fixed antenna station near Adam Creek mouth. Occurrences were recorded daily during 1 h intervals for 8 consecutive 12d periods.

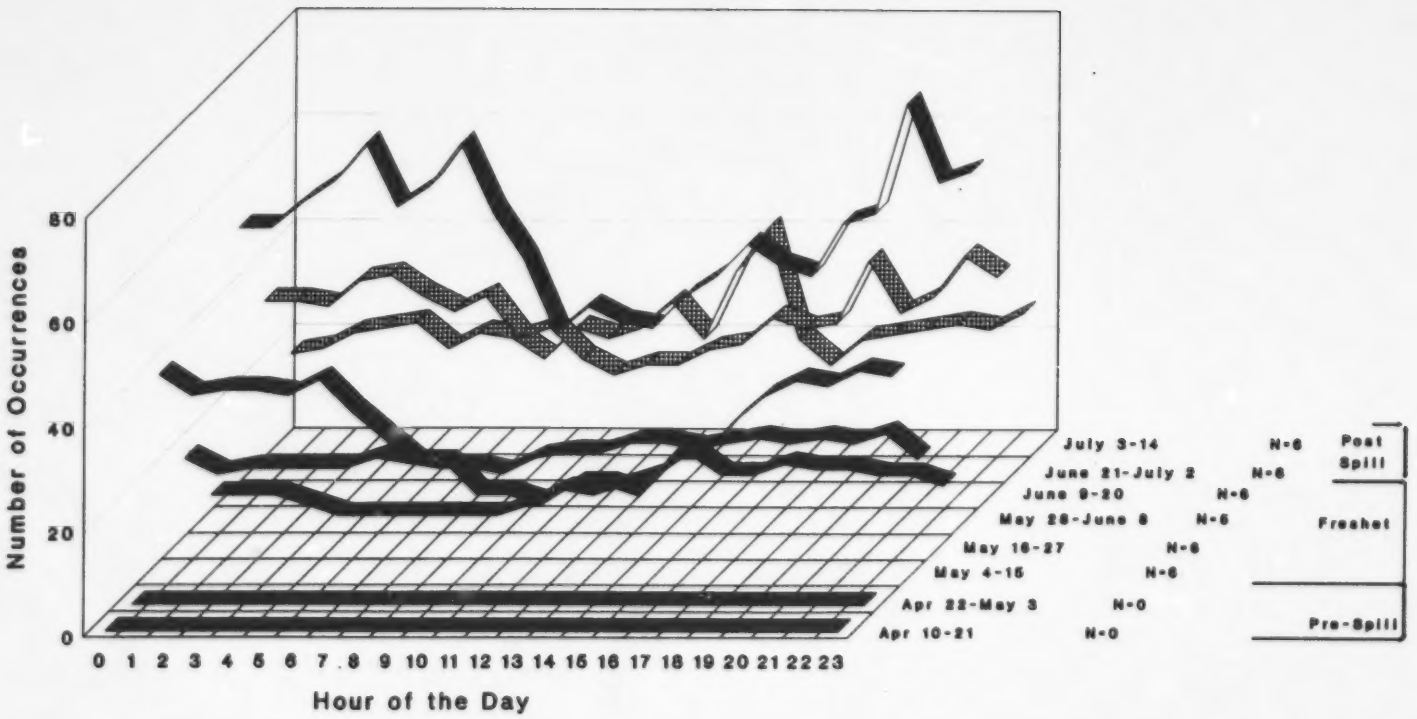


Figure 13

Total number of recorded 1989 occurrences of radio tagged lake sturgeon in the vicinity of the fixed antenna station downstream of the Adam Creek control structure. Occurrences were recorded daily during 1 h intervals for 8 consecutive 12 d periods.

Station 5, 1990 - Third Island, 3 km north of the Kipling GS

Only two occurrences of radio tagged sturgeon were recorded, and only for a brief period of time (once within 1 h), 2 km north of the Kipling GS. Despite the location and apparent suitability (shallow, rubble substrate, increased current), this area of the Mattagami River does not appear to be used by lake sturgeon as a spawning site.

Station 6, 1990 - At the mouth of Adam Creek

Lake sturgeon were not observed to congregate in the vicinity of the mouth of Adam Creek prior to or during freshet (Figure 15). The greatest number of occurrences were recorded following freshet and therefore suggests that the gravel/rubble beds located just west of the mouth of the creek are not used as a spawning site.

Stations 7, 8, and 9, 1990 - south of Little Long GS forebay

Overall, the greatest number of occurrences throughout the three periods (pre, freshet and post) was recorded at station 9 (confluence of the Groundhog and Mattagami Rivers). The number of recorded occurrences decreased steadily in a northerly direction (*i.e.* towards Little Long GS - stations 8 and 7). The number of recorded occurrences of tagged fish at the station closest to Little Long forebay (station 7, Figure 16a, b, c) was similar (n=8) to the number recorded in 1989 at station 3 (Figure 8).

4. DISCUSSION

Walleye, 1989

Walleye spawning has been reported to occur in the spring shortly after ice break-up at water temperatures of 5.6°C - 11.1°C (Scott and Crossman 1973 and Colby *et al.* 1979) and as early as 4.4°C - 5.6°C (Rawson 1957). Water temperature in Adam Creek after the first five days of spilling was 10°C (surface). This observation combined with the collection of ripe males from the tailrace of Kipling GS at a water temperature of 9°C suggested that any walleye within Adam Creek may have been in spawning condition. The spent condition of the females captured at Kipling GS tailrace suggested that spawning may have occurred during the spill.

Several mark-recapture studies involving walleye have provided evidence that adults return to the same spawning sites each year (Stoudt 1939, Olson and Scidmore 1962 and Forney 1963). Furthermore, Crowe (1962) indicated that where netting was repeated in subsequent years, many tagged walleyes were recaptured at the location where they were tagged previously. The occurrence

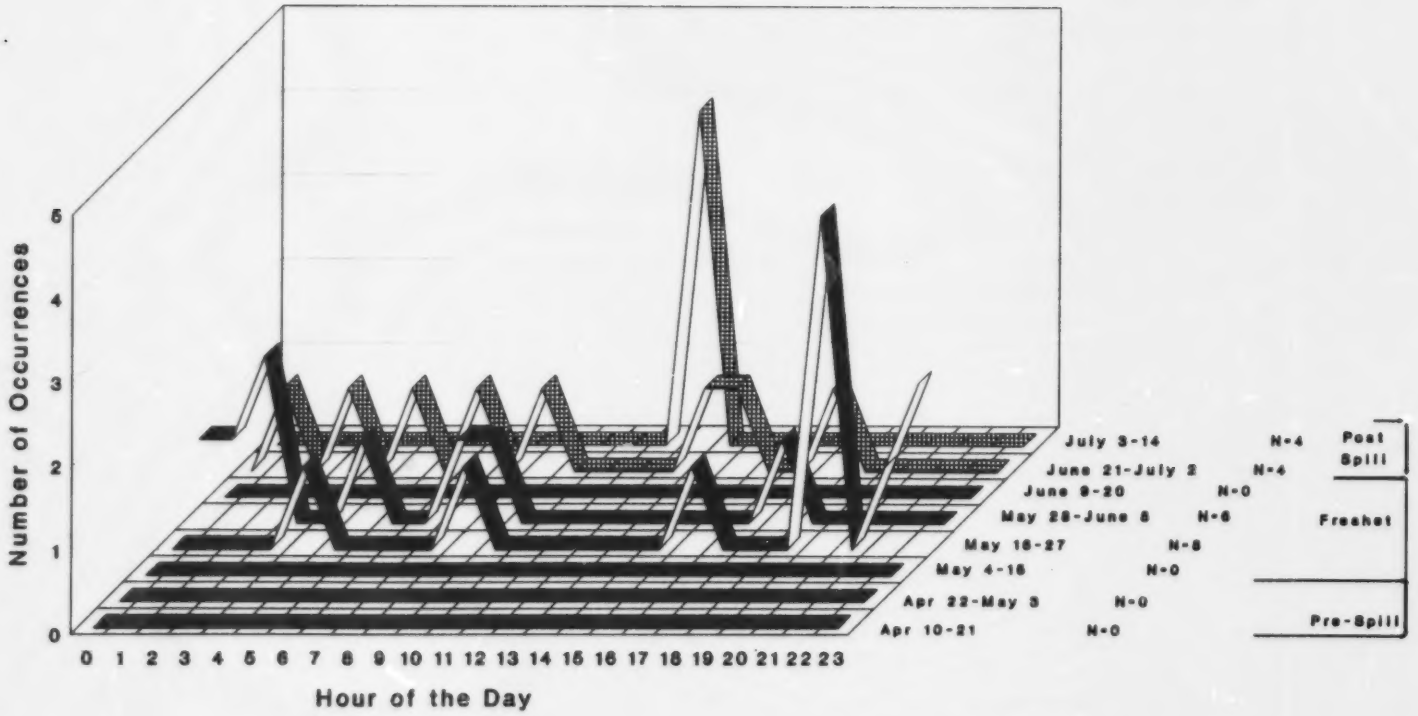


Figure 14

Total number of recorded 1989 occurrences of radio tagged lake sturgeon in the vicinity of the fixed antenna station in the vicinity of the Mattagami River and Little Long GS forebay. Occurrences were recorded daily during 1 h intervals for 8 consecutive 12 d periods.

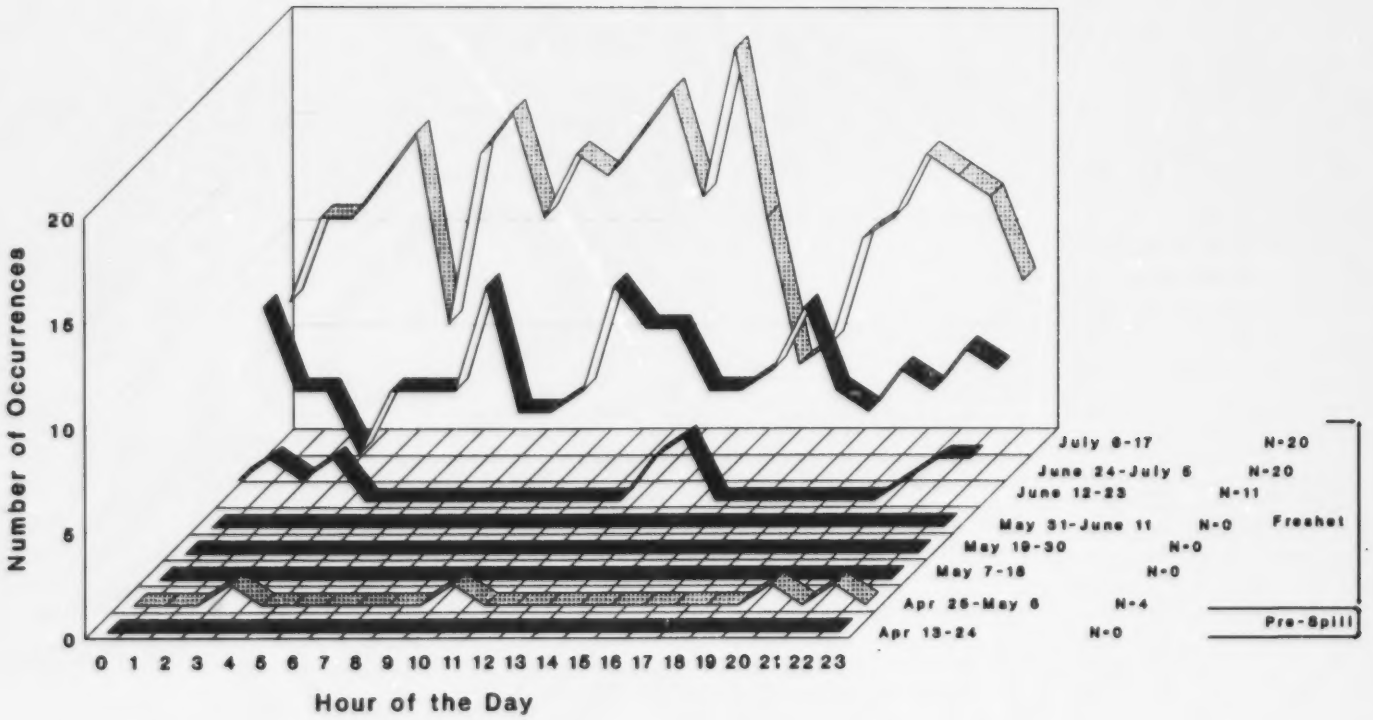


Figure 15

Total number of recorded 1990 occurrences of radio tagged lake sturgeon in the vicinity of the fixed antenna station located on the Mattagami River near Adam Creek mouth. Occurrences were recorded daily dirng 1 hr intervals for 8 consecutive 12 d periods.

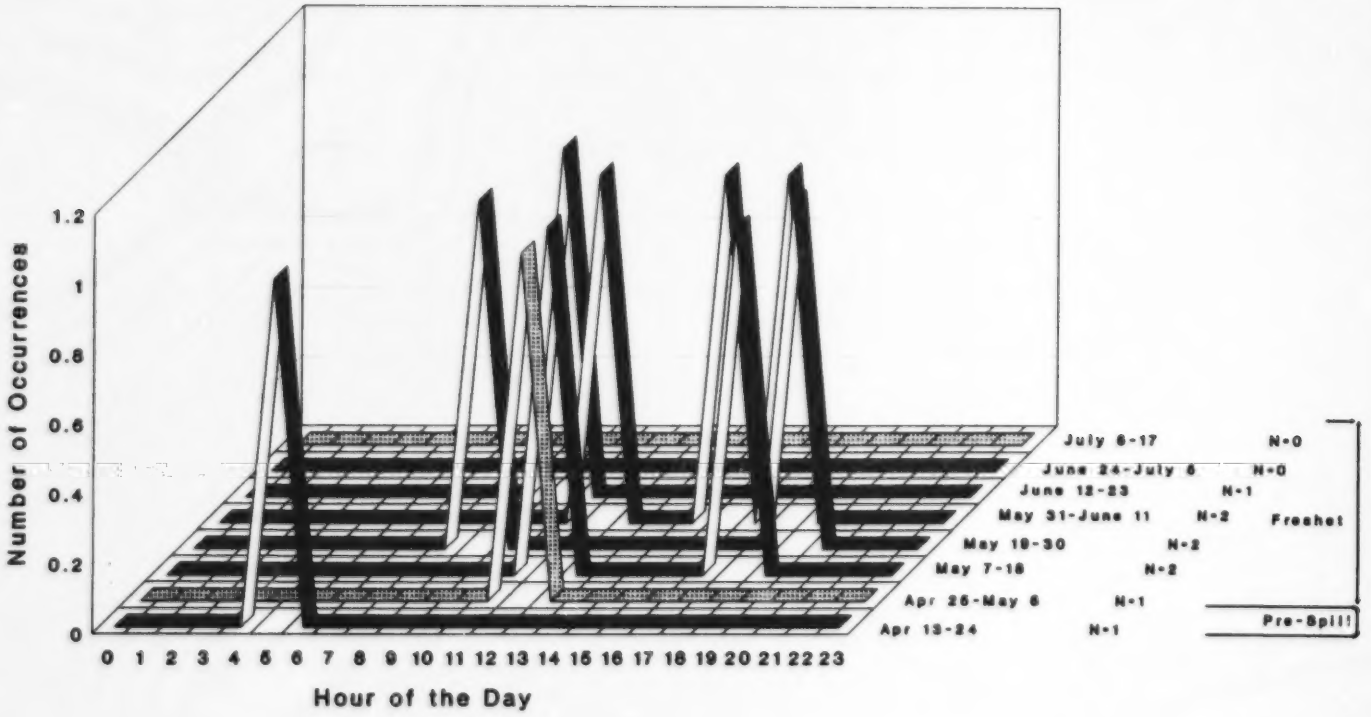


Figure 16 a

Total number of recorded 1990 occurrences of radio tagged lake sturgeon in the vicinity of the 3 fixed antenna stations located on the Little Long GS headpond. Occurrences were recorded daily during 1 h intervals for 8 consecutive 12 d periods.

a - Burnt Island

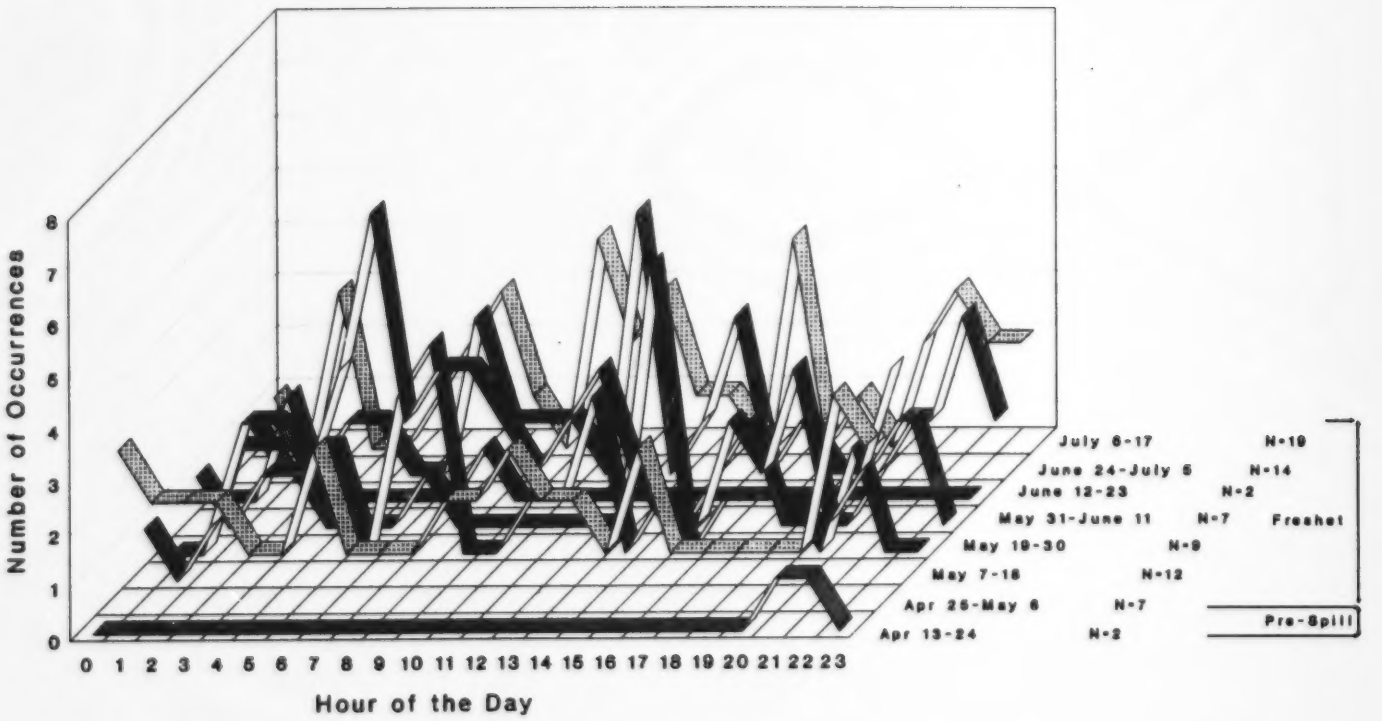


Figure 16 b

Total number of recorded 1990 occurrences of radio tagged lake sturgeon in the vicinity of the 3 fixed antenna stations located on the Little Long GS headpond. Occurrences were recorded daily during 1 h intervals for 8 consecutive 12 d periods.

b - south confluence of Mattagami and Kapuskasing Rivers

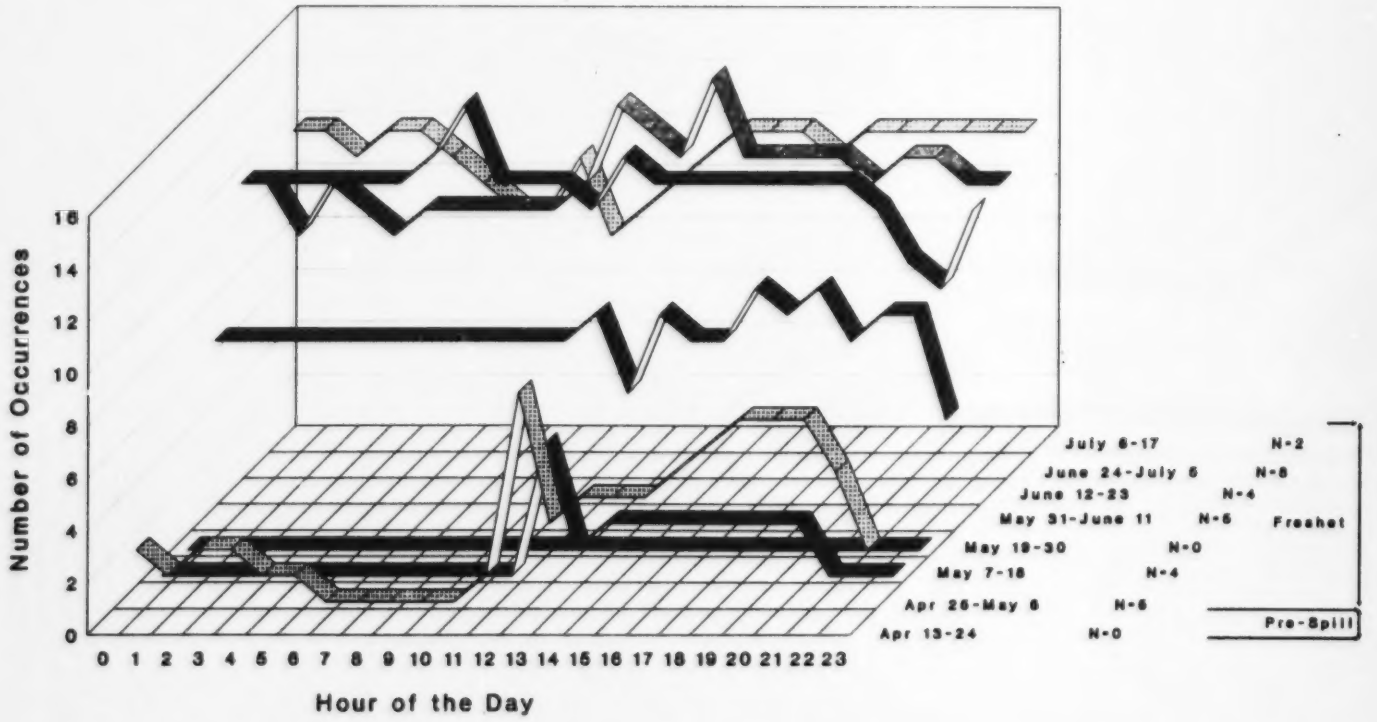


Figure 16 c

Total number of recorded 1990 occurrences of radio tagged lake sturgeon in the vicinity of the 3 fixed antenna stations located on the Little Long GS headpond. Occurrences were recorded daily during 1 h intervals for 8 consecutive 12 d periods.

c- confluence of Mattagami and Groundhog Rivers

of our radio tagged walleye just 2.5 km upstream from where they were caught, tagged and released therefore is perhaps not surprising. Their occurrence in Adam Creek, 3.5 km upstream from its mouth, following freshet supports a previous hypothesis which suggested that movement following post-spawning does not appear to be extensive and they may select the same general location for feeding in successive years (Olson *et al*. 1978).

The increase in walleye activity (Adam Creek, recorded occurrences) at night was typical. This behavioral activity has been reported in studies which compared catches from night and day net sets (Carlander and Cleary 1949 and Rawson 1957). It was assumed that the difference in catch from these studies was an indication of greater activity at night rather than greater ability to re-avoid the nets during the day. Holt *et al*. (1977) provided direct evidence of increased activity during the late afternoon and early morning interval from the tracking of radio tagged, lacustrine walleyes. Observations made during this study provided direct evidence of increased activity during the late evening and early morning hours for riverine walleye. Walleye spawning occurs during the night (Scott and Crossman 1973). The increased activity observed in Adam Creek during the late evening and early morning may also have been attributable to spawning behavior.

The recorded occurrences of walleye during the post spill period suggested that these fish are not restricted in their movement between Adam Creek and the Mattagami River.

Any negative influence the surgical procedure may have had on the radio tagged walleyes appears to have minimal: all of these walleye were recorded 2.5 km upstream into Adam Creek approximately five months after surgery despite periods of strong currents. Further evidence that the procedure may have had a minimal effect on the feeding behavior of these walleye is that one individual was caught by an angler seven months after surgery. The angler reported that the individual was in good condition.

Lake Sturgeon

The migratory behaviour (direction and distance) of lake sturgeon has been shown to be site specific. Sandilands (1987) reported that during the first year of his mark-recapture study in the Kenogami River, 84% of the sturgeon recaptures had only moved 1-3 km. The maximum distance traveled appears to have been 13 km. During the second year of study, he reported distances traveled of 130 and 150 km for a few individuals. The direction was upstream in the spring and downstream in the fall. A second mark-recapture study conducted on the Groundhog and Mattagami Rivers reported that 52% of the recaptures exhibited no movement (Nowak and Jessop 1987). Of the individuals exhibiting any movement, the direction was predominantly downstream for 6-20 km. During the present 2-year study, all (94%) but one of the sturgeon radio tagged south of Little Long GS initially moved upstream in the fall (1988 and 1989) for at least 30 km and generally overwintered in this area. Approximately, only 42% of the radio tagged sturgeon exhibited a second

downstream and upstream migration (approximate 60 km round trip) following spring freshet.

The limited movement of juvenile sturgeon within the study area suggests that any passage through the control structures at Adam Creek or through Little Long GS is minimal, at least during the late fall and winter periods.

The vulnerability of adult lake sturgeon to passage over dams and over barriers or being attracted into the base of dams and spillways and subsequently trapped once the water levels subside has been expressed by several authors (Thuemler 1985 and Auer 1988). Results from the present study indicated that only 42% of the radio tagged sturgeon were present during spill in the forebay of Little Long GS and therefore, vulnerable to passage through Ontario Hydro facilities. Of these, only one had passed through Little Long GS. The majority of the radio tagged sturgeon were situated at least 30 km south of the forebay before the end of freshet. The greater freshet period in 1990 than 1989 does not appear to have increased the chance of passage for any of the radio tagged sturgeon into Adam Creek or through Little Long GS.

Results also indicated that despite individuals being trapped in the pools north of Adam Creek control structure or in pools just below the North Falls on Adam Creek, these fish can survive at least for two overwintering periods. The sturgeon tagged below North Falls subsequently escaped (or retreated) to the Mattagami River.

While the weight and length characteristics of the sturgeon caught during the present study were less than the values reported for sturgeon collected in the Groundhog and Mattagami Rivers by Nowak and Jessop (1987), the latter study had used larger mesh nets. Although sample sizes between the former and present study are not equal, the reason for the difference in the number of male and female sturgeon caught between the present (3 males: 1 female) and the previous study (1:1) is not apparent. The differential in male/female ratio may be due to sampling location (spawning area, Nowak and Jessop 1987) and sampling date.

Spawning of lake sturgeon has been shown to be temperature dependent but over quite a wide range. Scott and Crossman (1973) suggested spawning temperatures were between 13 and 18^{o}C whereas Kempinger (1988) reported spawning activity in Wisconsin to occur over a temperature range of 8.3 - 23.3^{o}C. Furthermore, the latter study reported two peaks in spawning activity, one at 10 - 14^{o}C and a second at 13 - 16^{o}C. In addition to the appropriate water temperature, spawning sturgeon were shown to prefer shallow water with current velocities exceeding 15 cm/s (Kempinger 1988). The 3^{o}C warmer water in Adam Creek than in the Mattagami River during the freshet, likely due to the runoff into the creek from other streams, as well as the turbulence in Adam Creek may have induced those sturgeon in the vicinity of the Adam Creek/Mattagami River confluence to move up and into the Adam Creek to spawn in 1989. C. Jessop (MNR, pers. comm. to R.W. Sheehan) reported that sturgeon have usually spawned by the end of May in the Little Long vicinity.

An increased activity pattern for lake sturgeon during the evening and early morning hours does not appear to have been reported prior to this study. Any direct comparisons with other studies therefore cannot be made. It has been reported however that juvenile Russian sturgeon displayed a vertical migration where they remained near the bottom during periods of maximum light intensity and moved up in the water column at night (Levin 1981).

Kempinger (1988) noticed that peak spawning periods generally last only one day and only occasionally for 3 - 6 days. The increased activity of the radio tagged sturgeon in Adam Creek during freshet, therefore, may not have been attributable to spawning alone, but perhaps indicative of increased feeding behavior since the high water level and current in the creek may have resulted in elevated levels of available food items.

Any negative effect the external attachment procedure may have had on the sturgeon appears to have been minimal since the majority of these fish (>80 %) tagged either north of Kipling or Little Long GS were located almost a year later on several occasions at positions upstream and downstream from where they were originally released. The capture of two individuals by anglers suggested that any influence on feeding behaviour was likely minimal.

5. LIMITATIONS AND RECOMMENDATIONS - RADIO TELEMETRY

1. Tracking of radio tagged individuals within a large river system requires the use of both fixed antenna sites and aircraft. Aircraft enables the coverage of great distances, particularly useful for migratory species, whereas fixed antenna sites allow for the continuous surveillance of points of interests (*i*.e. dam sites).

2. It is recommended that the interrogation of data loggers be remotely controlled and powered. A considerable amount of time (monies) could be saved if crews did not have to visit each site at frequent intervals. The software required to interrogate our data loggers remotely is available as well as the technology to transmit the data.

3. Reconnaissance flights must be conducted frequently, especially during important environmental events such as freshet, and throughout the year to ensure adequate coverage of a study area. The flight plan followed during the above study is recommended. Calibration checks of the observer accuracy in locating radio tags must be carried out.

4. Attempts to assess any potential effect an implanted or attached tag may have on a fish should be made. Attempts at re-capturing tagged fish therefore is recommended, recognizing that re-capturing individuals in a large river is extremely difficult and costly. It is therefore recommended that all studies be locally advertised, as was done with this study. This may ensure public assistance in returning any captured tagged fish for assessment of any effects.

5. Calibration and coverage checks of all fixed antenna sites, as conducted in above study, is recommended to ensure accurate and reliable data retrieval.

6. SUMMARY

1. Only one of the 29 radio tagged lake sturgeon was present in the forebay of Little Long GS prior to spring freshet in either year. The majority of these fish (94%) were located at least 30 km south of the forebay. During freshet of 1989, 42% (n=8) of the radio tagged sturgeon were located in the forebay. A similar trend was noted in 1990. Only 21% (n=4) were present during the monitored post spill period (July - in 1989 and 1990). One of these individuals did eventually pass through Little Long GS in the late fall of 1989 and was last located in the forebay of Smoky Falls GS.

2. All six radio tagged lake sturgeon in 1989 and 5 in 1990 successfully overwintered in pools just north of the spill control structure on Adam Creek. These individuals were not permanently displaced following spilling. Those individuals which were displaced downstream during freshet returned shortly after freshet. One individual was removed from Adam Creek in the fall of 1989 by an angler. All remaining radio tagged sturgeon had successfully survived, as evident from their movement, below the control structure for at least two winters.

3. Two of the three radio tagged sturgeon originally tagged in Adam Creek in 1989 left the pools just below the North Falls at least one month prior to freshet and apparently escaped or retreated to the Mattagami River.

4. All twelve lake sturgeon, radio tagged north of Kipling GS, periodically moved into Adam Creek prior to spilling and remained there during spilling. All but one sturgeon were present during the last post-spill monitoring interval. Sturgeon activity, indirectly recorded as the number of occurrences, was greatest between 2100 h and 0800 h for the pre-spill and spill periods.

5. The area immediately north of the third island (north of Kipling GS) was not frequented by lake sturgeon during the spawning period in 1990.

6. All fifteen walleye, radio tagged at the downstream end of Adam Creek in 1989, were periodically, located 2.5 km upstream in the creek during the pre-spill and spill periods. All remaining individuals were also present during the last post-spill monitoring period. This movement coincided with their suspected spawning period. Walleye activity, indirectly recorded as the number of occurrences, was greatest between 2400 h and 0800 h for the pre-spill and spill periods.

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Approved by:

D.J.R. Dodd
Manager
Chemical Research Dept

Submitted by:

R.S. McKinley
Associate Research Biologist
Biological Research Section

Reviewed by:

A.M. Sills
Section Head
Biological Research Section

R.W. Sheehan
Field Biologist
Biological Research Section

H.E. Kowalyk
Lead Technician
Biological Research Section

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